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Resisting-accepting-directing sea level rise on the Chesapeake Bay: Agricultural producers' motivations and actions

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ABSTRACT

As relative rates of sea level rise accelerate in the Mid-Atlantic region of the United States, the frequency of flooding and saltwater intrusion on coastal lands also increases, prompting ecological transformation which can conflict with existing coastal land use such as agriculture. We performed an exploratory study of coastal farmers and woodlot managers in Maryland and Virginia to understand how these producers make land management decisions within the context of sea level rise. Specifically, we used a mixed-methods approach to identify and understand 1) the producer-observed impacts of sea level rise and flooding on coastal lands; 2) the range of actions producers may take in response to sea level rise and flooding; 3) producers' intentions for managing their land in the short- and long-term; 4) producers' motivations for selecting a particular response; and 5) the additional support coastal producers need to successfully adapt to sea level rise. We used the Resist-Accept-Direct framework as an analytical tool to understand how producers' actions and motivations align with 1) prevention or removal of impacts from flooding and saltwater intrusion, 2) accommodation for wetter or saltier conditions as they naturally occur, or 3) facilitation of specific changes toward a new desired outcome. We found that while most producers in our study plan to resist or accept changes over the next five years, over the longer term a majority of participating producers plan to transition land to a use that is compatible with increased saltwater intrusion and flooding. Most producers in our study would prefer to continue farming yet face a lack of effective and/or affordable management options to resist ecological changes. Flexible mechanisms that support producers in resisting sea level rise impacts in the short term, while supporting them in directing the transition of their land to another productive use in the long term, are needed to support coastal farmers as they adapt to a changing climate.

1. Introduction

Global climate change is occurring rapidly and prompting ecosystem transformation (IPCC, 2021). Resource managers around the world will have to decide how to respond to the effects of climate change. For example, sea level rise (SLR) is already causing chronic inundation of low topographic coastal areas, erosion of the shore, tidal flooding events, salinization of the soil, and the transitioning of coastal ecosystems and nearby uplands to wetter and saltier ecotones (Brinson et al., 1995; FitzGerald et al., 2008; Kirwan et al., 2016; Schieder et al., 2018; Titus and Wang, 2008). While these potential impacts of SLR on coastal landscapes are relatively well known, understanding how resource managers make decisions about whether to preserve current use of resources or transition to an alternative is lacking in the scientific literature and is necessary to inform relevant research and effective policy.

Coastal farmers are resource managers who face particular challenges as SLR exerts chronic change to the landscape. Increased wetness can waterlog soils, thus stunting plant growth and reducing crop yield (Sairam et al., 2008; Singh, 2017; Watson et al., 1976). Salinization (i.e., the accumulation of water-soluble salts in the soil) can occur via overland flooding (i.e., SLR, tidal flooding, and storm surge) or increasing saltwater intrusion (i.e., movement of saltwater into aquifers) (Gibson et al., 2021; MDP, 2019). For farmers, increasing salinization could exceed crop-specific salt tolerance thresholds, causing plant death or lower growth and yields (Gibson et al., 2021; Maas and Grattan, 1999;

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McNulty et al., 2019; Tully et al., 2019a). Furthermore, researchers found saltwater encroachment on farmland caused changes in ionic strength and sulfidation of soils, resulting in nitrogen and phosphorus release from the soil into surface waters, changing water quality (Tully et al., 2019a; Weissman and Tully, 2020).

Some farmers also manage forests as woodlots for timber, which are vulnerable to flooding and high salinity due to SLR. Waterlogged soils can stress trees by limiting root oxygen (Kreuzwieser and Rennenberg, 2014). Salinity stress is reported to decrease overall vigor, reduce ability to assimilate carbon, increase insect infestations (e.g., pine bark beetles), cause sparse crown, low growth, short needle length in pines, small foliage in hardwoods, and possible mortality (Gibson et al., 2021; Pezeshki et al., 1990). Forest regeneration is limited under flooded and saline conditions because tree seedlings generally require moist but not saturated conditions to grow (Kirwan et al., 2007).

The degree of vulnerability to SLR impacts on a farm or woodlot in the coastal zone depends on topographic features and weather events. Nearshore, low topographic areas are in greater jeopardy of chronic exposure to overland flooding and saltwater intrusion (Rowley et al., 2007). The frequency and duration of episodic weather events, such as storm surge, as well as the availability of freshwater (e.g., precipitation, irrigation) to remove salts from the soil and groundwater influences how much the soil or vegetation is affected (Gibson et al., 2021). Furthermore, artificial hydrological connectivity structures (e.g., tide gates, levees, ditches, canals) intended for drainage have also become conduits for saltwater (Bhattachan et al., 2018; Tully et al., 2019b). When saltwater levels become high enough (i.e., due to storm surge or high tide flooding) to overtop tide gates or levees, these structures then trap the water and their associated marine salts on land (Walsh and Miskewitz, 2013). The combination of how long saltwater is present on the land and what crops are exposed can cause gradual or sudden declines in agricultural productivity.

Options to combat or adapt to flooding and saltwater intrusion include remediating soils (e.g., using irrigation to flush salts from soils, adding gypsum to disperse sodium ions, applying low-salt manure or compost, and/or using cover crops), engineering solutions to prevent flooding or encourage drainage (e.g., tide gates, levees, ditches), and changing to more salt-tolerant crops. Each of these options has site-specific return on investment for farmers and woodlot managers who must consider thresholds for effectiveness, upfront costs, available markets, and possible returns (Gould et al., 2020; Saacke Blunk et al., 2020; Tully et al., 2019b).

While increased wetness and salinity are detrimental to traditional agricultural crops and woodlots, tidal wetland plants favor these conditions (Gedan et al., 2020; Linhoss et al., 2015). The invasive halophyte *Phragmites australis (Phragmites)* is a highly opportunistic wetland plant that commonly spreads under these conditions (Chambers et al., 1999; Gucker, 2008), moving into woodlots as trees die (Kirwan and Gedan, 2019) and often becoming the dominant species in agricultural fields that are abandoned or allowed to go fallow due to wet and saline conditions (Gedan and Fernández-Pascual, 2019). The spread of undesired wetland plants like *Phragmites* can be managed with herbicide application or manual removal; however, repeated treatments are required and recolonization is common (Berger, 1993).

Several regional conservation organizations and agencies seek to incentivize the purposeful transitioning of agricultural land to wetlands. Tidal wetlands are valued for the numerous ecosystem services they provide (Barbier et al., 2011), including their potential to sequester carbon, yet they are vulnerable to inundation from SLR (Kirwan and Gedan, 2019). Under the right conditions, tidal wetlands can migrate inland—a process called "marsh migration"—thereby recovering the area lost to SLR (Kirwan and Gedan, 2019). The United States Department of Agriculture (UDSA) as well as other state and non-profit agencies offer a range of conservation and easement programs to financially incentivize conservation practices, including support to protect or restore wetlands (USDA FSA, 2022; USDA NRCS, 2021). There is a tradeoff however, as programs designed for wetland restoration generally preclude the continued farming of that area, and may also exacerbate inequities (see Van Dolah et al., 2020).

Facilitating the migration of tidal wetlands onto coastal farmland may be an appealing management goal for some stakeholders in the region; however, alternatives—such as protecting farmland from flooding—may be more appealing to other stakeholders. That is, strategies for coastal land management in the face of SLR might include resisting, accepting, or directing change. These alternative approaches have been formalized as the Resist-Accept-Direct (RAD) framework, which is a simple tool that helps decision-makers consider the full range of possible actions they may take in managing ecosystems that are facing the possibility of rapid and irreversible change (Lynch et al., 2021; Schuurman et al., 2020; Thompson et al., 2021). For example, Lynch et al. (2021) applied the RAD framework in the context of several federal National Wildlife Refuges (NWRs) experiencing accelerated salt marsh and barrier island loss along the mid-Atlantic coast. Selected land management strategies differed across the three NWRs and included: a resist approach at the John H. Chafee NWR to maintain marsh elevation by applying thin sediment layers to marshes; an accept approach at Chincoteague NWR which allows island migration and dune overwash to continue; and a direct approach at Blackwater NWR to acquire uplands adjacent to an eroding marsh to allow for landward marsh migration. Decision-making factors not only include effectiveness and durability of the strategies for maintaining an ecological state, but also the social acceptability and economic feasibility of each strategy (Lynch et al., 2021; Schuurman et al., 2020).

In our study, we applied the RAD framework to help us analyze the motivations and management actions of coastal farmers and woodlot managers (hereafter, "producers") in response to the potential for rapid and irreversible change to the landscape due to SLR. This paper presents the main findings from our study, including 1) the producer-observed impacts of sea level rise and flooding on coastal lands; 2) the range of actions producers may take in response to SLR and flooding; 3) producers' intentions for managing their land in the short- and long-term; 4) producers' motivations for selecting a particular response; and 5) the additional support coastal producers need to successfully adapt to SLR. We also discuss 1) the effectiveness of applying the RAD framework within the context of private land management, 2) opportunities for research and policy, and 3) limitations to the study. Our insights on what factors influence producers' land management decisions can help to inform future research, programming, and collaboration to support producers' adaptation to SLR and achieve shared goals for the region.

2. Methodology

2.1. Study region

Agriculture is a large commercial industry in both Maryland and Virginia, employing thousands of people, contributing billions of dollars to the economy, and covering significant land acreage (Maryland Manual On-line, 2022b; VDACS, 2022). Agriculture occupies 32% of total land area in Maryland and 28% of the land area in Virginia (Maryland State Archives, 2021; VDACS, 2022). On the Delmarva Peninsula (which includes parts of Delaware, Maryland, and Virginia; see Fig. 1) there are 1.3 million acres of farmland, 1.7 million acres of wetland, 450,000 acres of forest, and 3.2 million acres of grassland (Delmarva Restoration and Conservation Network). There is also an extensive ditch network in the Delmarva region, which has historically been used to drain water off agricultural lands. In Maryland's portion of the Delmarva Peninsula (known as the Eastern Shore) there are 821 miles of recorded "tax ditches" (i.e. ditches established and maintained by public drainage associations authorized under the Maryland Drainage Law, revised 2013, MD Code, Local Government, § 26–1102) and an estimated 1000 miles of smaller, on-farm ditches. The tax ditches drain about 183,000 acres of cropland, forest land, commercial, and

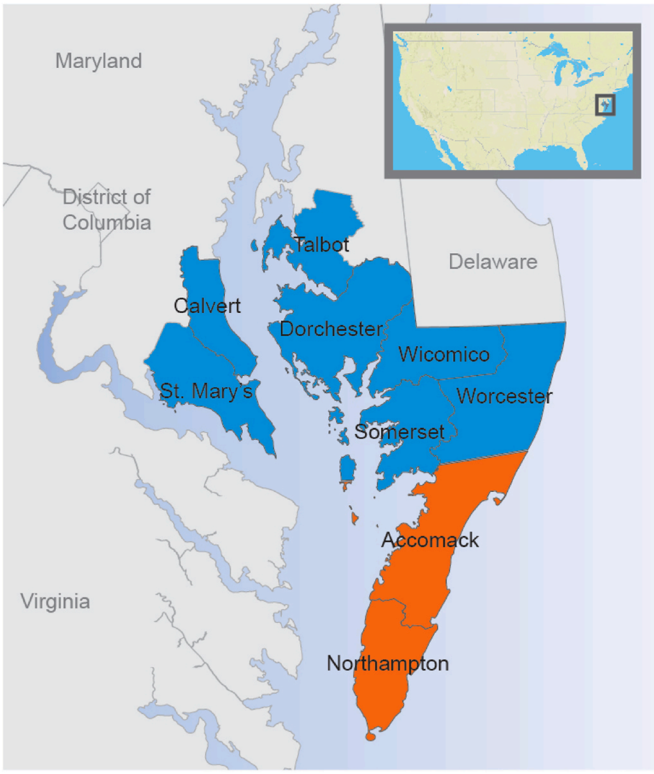

Fig. 1. Map of the Delmarva region with counties in Maryland (blue) and Virginia (orange), USA in which project participants' farms and woodlots are located. (We do not have location information for the farms and/or woodlots for nine of the 35 participants.).

residential areas, or approximately 8% of the total land area of Maryland's Eastern Shore (Maryland Department of Agriculture).

Coastal Maryland and Virginia include Chesapeake Bay-side and Atlantic-side shores, where rates of relative SLR are four times greater than the global average due to a combination of eustatic increase and land subsidence (Church et al., 2013; Sallenger et al., 2012). Agricultural and forest land are currently being inundated by SLR in coastal Maryland and Virginia (see Gedan et al., 2020; Titus et al., 2010), where saltwater intrusion is estimated to have affected 50,406 acres of forest in Dorchester, Wicomico, Somerset, and Worcester counties in Maryland (USDA Forest Service and MD DNR, 2017).

2.2. Participant recruitment

Because our objective was to develop an in-depth understanding of how coastal producers make decisions about land management in response to SLR, we used a non-probabilistic purposive sampling approach (Bernard, 2006) to identify and recruit producers who own or lease farmland and/or woodlots in Maryland and Virginia and who self-identified as being currently or imminently affected by tidal flooding and/or saltwater intrusion. Potential participants were identified by the project's steering committee and agricultural partners (e.g., University agriculture extension offices, soil conservation districts, USDA Natural Resources Conservation Service (NRCS), the USDA Farm Service Agency, and individual producers) from September to December of 2020. These agricultural partners helped recruit participants through emails to their electronic mailing lists and announcements in newsletters. We also advertised the project in *The Delmarva Farmer*, a local newspaper. Identified potential participants were then recruited via phone or email. Participating producers were offered reimbursement commensurate with their participation in study activities (i.e., up to $250; $20 per survey, $70 per workshop).

2.2.1. Profile of participants

We collected data on gender, age, race, property ownership, acreage farmed, and crops grown from 29 pre-workshop survey respondents and additional information gathered from six participants who did not complete the pre-survey (Table 1; n = 35). The majority of participating producers self-identified as white males who owned and managed their land (Table 1). Producers' managed properties were located in nine different counties across Maryland and Virginia (Fig. 1).

2.3. Data collection

2.3.1. Semi-structured interviews

In September and October of 2020, we conducted semi-structured interviews with 11 participants. The semi-structured interviews were guided by nine open-ended questions on interviewees' observed changes to the landscape, challenges in management, ways interviewees have altered management, and interest in available management techniques or research. A semi-structured format was used to give interviewees flexibility in their responses, allowing for further inquiry as different issues arose, while still maintaining comparability across interviews (Bernard, 2006). Interviews were conducted over the phone and each lasted approximately 30–60 min. Audio recordings of the interviews were transcribed (i.e., converted to written text) using WeTranscribe software and then reviewed for accuracy before being analyzed as described in Section 2.4.

2.3.2. Pre-workshop survey

Interview responses helped to inform the creation of a pre-workshop survey which was distributed to producers in November 2020. The pre-workshop survey contained 29 questions pertaining to the characteristics of their land, environmental changes producers have seen on their

Table 1
Demographics of project participants (n = 35).

Participant Demographics	Number of Participants	Participant's Property Demographics	Number of Participants
Gender		Ownership of property	
Female	6	Own and manage	21
Male	23	Own and lease	4
Unspecified	6	Rent and manage	4
Race and Ethnicity		Unspecified	6
White	25	Farm acreage	
Black	3	0	1
Hispanic	0	1-100	11
Unspecified	7	101–1000	7
Age		1001–3700	9
18-29	1	Unspecified	7
30-39	2	Woodlot acreage	
40-49	5	0	2
50-59	8	1-100	13
60-69	6	101–1000	5
70-79	6	1001–3000	4
80-89	1	Unspecified	11
90–99+	1	Type of crops farmed[a]	
Unspecified	5	Vegetables/Herbs/Fruits	12
Years spent farming		Grains[b]	17
0-1	2	Unspecified	10
2-10	5		
11-20	3		
21-30	5		
31-40	3		
41-50	8		
51-60	1		
61-70	1		
Unspecified	7		

[a] Type of crops farmed pertains only to farm acreage. Participants could be counted twice for farming both types of crops.
[b] Grains included corn, barley, soybeans, wheat, sorghum, rapeseed, miscanthus grass.

land, what land management topics were of greatest interest, demographics, and virtual meeting preferences. The survey was created in SurveyMonkey – an online survey tool – and distributed to existing study participants (n = 17) through an emailed link. In two cases, we mailed a paper survey to producers who indicated that as their preference. We also asked 25 of our network partners (e.g., University agriculture extension offices, soil conservation districts, the USDA NRCS, and the USDA Farm Service Agency) to share a link to the survey with their network of producers as a method to recruit more responses and possible participants. We received a total of 29 pre-workshop survey responses.

2.3.3. Online workshops

Between December 2020 and March 2021, we hosted three online, 90-min workshops on Zoom — a virtual meeting platform. Pre-workshop survey results helped inform the topics for presentations and discussion. Fourteen producers attended each workshop (though not the same individuals each time) in addition to project team members, notetakers, and breakout room facilitators. Online workshops were recorded and transcribed. In addition, notetakers were assigned to each small-group discussion breakout room. Notetakers met with the project team members shortly after each workshop to debrief on the main points that arose.

The three workshops had the following design and content.

- Workshop 1 included a presentation by an agroecologist on current and projected SLR impacts to agriculture productivity followed by small-group discussions with producers to hear from them about their experience with flooding and salty conditions and their land management goals.
- Workshop 2 included presentations on existing SLR management opportunities followed by small-group discussions with producers on the advantages and disadvantages of six possible management techniques (i.e., improving drainage, remediating salty soils, salt-tolerant crops, conservation easements, wetland plant management, recreation opportunities, and carbon credits).
- Workshop 3 included a Maryland Sea Grant presentation on the future coastal effects of SLR and stories from three workshop participants about how their land has changed and their future production plans. The majority of time was for producers to share their concerns with invited policymakers and researchers.

2.3.4. Post-workshop survey

On April 5, 2021, we sent a post-workshop survey via SurveyMonkey to 30 study participants. We received 20 responses for a response rate of 57%. The survey contained 17 questions about producers' intentions for future management of their farmland and/or woodlots, desired future programs and research, and the value of the workshop content.

Central to the results we present in this paper are the responses to the post-workshop survey question: "Knowing what you do now about saltwater intrusion and flooding, which course of action are you most likely to pursue in the short term (over the next 5 years)." Producers could select from one of three responses, which correspond to resisting, accepting, or directing, respectively.

1. Make efforts to protect land from saltwater intrusion and flooding (e.g., tide gates, berms, etc.).
2. Continue managing your land much as you have done in the past, accepting that some patches may become unsuitable for farming.
3. Transition the land to a use that is compatible with increased saltwater intrusion and flooding (e.g., conservation easement, hunting, carbon credits).

We also posed the same question and answers but over a long-time scale (i.e., "… to pursue in the long term (5 years from now and into the future)").

Post-survey respondents were also asked to review a list of 16 programming and/or research topics (compiled based on responses to the interviews, pre-survey, and workshop discussion questions) and indicate the three topics they felt were most important to be addressed by agencies in the future. For our analysis, we categorized each of these topics as aligning with either a Resist, Accept, and/or Direct approach.

2.4. Data analysis

Our team adapted the RAD framework as a method to analyze coastal producers' perspectives on management of private lands (Table 2). We

Table 2

Resist-Accept-Direct (RAD) definitions and associated land management actions. The study definitions adapt those of Schuurman et al. (2020) to specify what "resist", "accept", and "direct" would mean for coastal producers responding to sea level rise and/or coastal flooding. We did not use the RAD framework when discussing actions with producers; rather, actions were later classified as part of our data analysis.

	Resist the trajectory of change	Accept the trajectory of change	Direct the trajectory of change
Schuurman et al. (2020) definition	Work to maintain or restore ecosystem processes, function, structure, or composition based upon historical or acceptable current conditions.	Allow ecosystem processes, function, structure, or composition to change, without intervening to alter their trajectory.	Actively shape ecosystem processes, function, structure, or composition toward desired new conditions.
This study's definition	Work to prevent cropland/ woodlots from flooding and/or becoming salty; or to remove water and/or salt from the property.	Allow the cropland/ woodland to become wetter and saltier as sea level rise and/or coastal flooding naturally occurs.	Facilitate specific changes in cropland/woodlot wetness and saltiness toward a new desired outcome/scenario.
Description of Land Management Actions	Installation of structures, regrading land, or applying soil amendments to prevent cropland/ woodlots from flooding and/or becoming too saline.	Measures not taken to prevent flooding/ salinization or measures taken to facilitate a new land use or ecosystem equilibrium (i.e. adopt a use other than farming/ woodlot management). Work within the wet/saline conditions as they naturally occur.	Actions taken to facilitate the transition to a land use other than farming which sustains itself with wet/saline conditions caused by sea level rise (i.e. facilitate land transition into tidal wetland).
Examples of Land Management Actions	Tide gates, dikes and berms, drainage ponds, catch basins, and spillways to improve drainage; salty soil remediation.	Alternative crops (e.g., switchgrass, quinoa) and/or salt-tolerant crop varieties, work around wet/saline areas, letting affected land go fallow/ abandonment.	Conservation programs to incentivize transition to wetlands (e.g. Conservation Reserve Program, Wetland Reserve Easements, local/ state easement programs that require plantings or land manipulation for desired wetland composition and function), hunting/ recreation, ecotourism.

did not engage producers directly in considering RAD options, but rather used RAD as an analysis framework to understand openness and obstacles to actions aligning with resisting, accepting, or directing ecological change on coastal farmland. We designed our survey and interview questions to understand producers' motivations and concerns about management options that spanned the RAD categories. In Workshop 1, the agroecologist shared potential management actions in terms of "protecting," "accommodating," and "retreating," and we solicited feedback on those strategies from producers in small group discussion immediately afterward. In Workshop 2, we presented six options for managing coastal farmland and woodlots (see Section 2.3.3). Together, these management options represented the three RAD categories. We then facilitated discussion in small groups to hear the producers' perspectives on the advantages and disadvantages of each of the presented management options. From interview and workshop transcripts, we identified several examples of management actions that align with each RAD category (Table 2). In our post-survey (see Section 2.3.4), we asked about producers' short-term and long-term land use intentions with multiple-choice answers that corresponded to the RAD framework.

To understand producers' experiences with SLR impacts and motivation for making various adaptation decisions, we used analytical methods commonly employed with ethnographic data (Bernard, 2006). The interview transcripts (n = 11) and workshop transcripts (n = 3) were reviewed and coded for relevant themes. We used a grounded-theory or inductive coding approach whereby we allowed for new ideas and insights to emerge from close reading of the text. From the outset of this project, we were interested in understanding how SLR has impacted producers' farmland and woodlots, what management strategies they have employed, and what motivates them to select one management strategy over another; however, we did not have *a priori* hypotheses, but rather allowed important themes to emerge from the transcripts. Coded text was then categorized according to whether it aligned most with "resisting," "accepting," or "directing" the change in the ecological processes on coastal farmland. Surveys were analyzed using descriptive statistics.

3. Results

3.1. Producer-observed impacts of sea level rise and flooding

All of the producers participating in our study are already observing SLR-related changes on the lands they manage. In the pre-survey, producers indicated all observed conditions on their property from a list of 14 options (Table 3). The most common impacts reported by producers were "soils are wet longer" and "more standing water on the land." Notably all respondents (n = 29) indicated some effect on their property; no one responded that no changes had occurred or that they do not feel vulnerable to these threats.

Table 3
Conditions seen on property owned or managed by project participants as reported in the pre-survey (n = 29). These conditions are often related to sea level rise and flooding, but may also have other causes.

Conditions seen	% of respondents
Soils are wet longer	83%
More standing water on the land	74%
Increase in wildlife destruction	65%
Dead or dying trees	65%
More frequent ditch maintenance	62%
Increased wetland plants	61%
Flooding by seawater	52%
Erosion or loss of soil	48%
More salt in the soils	48%
Land no longer suitable for planting	46%
Reduction in crop productivity	42%
Increased costs to manage land	42%
Compromised infrastructure	27%
No changes and do not feel vulnerable to these threats	0%

The interviews and workshops provide further qualitative data on SLR impacts on producers' land. When asked, "Have you observed any changes in your land in the last few years? Have you noticed increased flooding?" 11 producers (10 out of 11 interviewees, 1 workshop participant) described flood conditions in terms of sources of flooding, flood frequency, extent, seasonality, and compromised ability to work the land. In addition, producers (n = 5) identified tributaries or ditches on their land that functioned as conduits for seawater and flooding. They reported wet conditions also increase fungal infections (n = 1), make land untillable (i.e. unable to be prepared for cultivation through mechanical turning of the soil) (n = 4), and risk machinery getting mired (n = 3). In response to the question, "Is the soil getting saltier?", nine producers reported the presence of salt on their lands. These included: accumulation of salt as a white crust on the soil surface (n = 2), the presence of wetland plants or wildlife (e.g., saltwater fish, jellyfish in tributaries) (n = 1), and signs of salt-stress in their crops (e.g., yellow soybean leaves or tree death) (n = 6). Multiple producers (n = 6) reported a decrease in crop production due to wet and saline conditions and how different crops, wetland plants, and conservation program plantings vary in susceptibility to these impacts.

Producers also noted changes in local flora and fauna. Four respondents described trees, shrubs, and wetland plants emerging and expanding on their lands. One producer described the appearance of ghost forests—stands of dead trees that were recently killed due to salt stress—occurring on their lower forest land. Producers (n = 3) noted *Phragmites* is prevalent in fields and ditches. They described *Phragmites* in the ditches slows drainage and that *Phragmites* is difficult to eradicate. With changing land conditions and shifting vegetation, producers have also seen associated changes in wildlife and described significant damage to crops caused by sika deer (*Cervus nippon)*, waterfowl, and beavers (*Castor canadensis*).

3.2. Land management actions that align with resisting, accepting, or directing

From interview and workshop transcripts we identified several examples of management actions for each RAD category (Table 2).

3.2.1. Actions that align with resisting transition

A few producers are actively attempting to resist the transition of their farmland to another type of land use. This involves installation of structures or land manipulation to prevent flood water from entering the property, facilitate drainage of flooded lands, or manipulate soil chemistry to reduce salinity (Table 2). Producers expressed the need to better understand their lands' hydrology and drainage potential: "I tried to attend any of the [agricultural] extension programs but most of the time those are with regard to farming and specific crops. They aren't necessarily helping me deal with the tidal flooding here on the property." Producers described the advantages and disadvantages of approaches to resist the transition of their farmland and woodlots to wetter, saltier land.

3.2.1.1. Dikes, berms & tide gates. Dikes, berms, and tide gates are structures designed to keep water from reaching the land. While an attractive option, they can fail. One producer confessed that their berm and tide gate had failed, causing water to back up into a field they were trying to drain. Another producer, with farmland along the Atlantic Coast, shared that they had a 6-foot dike around their farm with a drainage pipe and tide gate; however, the tide gate was starting to fail after a couple decades of use, and they were looking for a sturdier model. A third producer reported a tide gate has a life span of about 20–25 years; not long enough, since producers consider replacing one to be a significantly difficult task. Producers also described how tide gates can also fail to prevent flooding when they are blocked by debris or exceeded by a very high tide event.

3.2.1.2. Drainage ponds, catch basins, & drainage tiles. Drainage ponds, catch basins, and drainage tiles are structures designed to allow water that reaches a piece of land to drain away (see Vlotman et al., 2004). Several producers shared how their neighbors dug or re-dug ditches around their farmland, and this approach was considered effective for land drainage. Another producer dug a drainage pond, hoping water from the surrounding fields would run into it. This producer had some success but shared that the pond would need to be dug deeper in order to continue draining water from the fields in the coming year. Producers also described their success in using subsurface drainage tiles to direct standing water away from a crop area and in using catch basins to collect water in the field with small spillways to prevent water from coming back in. Producers viewed these approaches as relatively more affordable and less prone to malfunction than tide gates. However, subsurface drainage tiles are considered more of a temporary than a long-term solution; there is a chance of water flooding backwards, and water must be re-directed somewhere.

3.2.1.3. Remediating salty soils. If land is flooded by salty or brackish water, remediation of the soil may be necessary to continue to grow crops. Producers described a best practice of not tilling after noticing salt in the soil, but to let freshwater (i.e., precipitation) wash the salt off first. They also discussed the possibilities of using lime, organic matter, or gypsum to remediate salty soils. However, producers also shared how delaying the tilling of the ground can reduce crop germination, especially in cold and wet conditions, and gypsum can be a significant cost to apply over a large area. Many producers in our study did not perform soil salinity tests.

3.2.2. Actions that align with accepting transition

Producers also described the ways they are continuing to farm or maintain their land as it becomes wetter and more saline due to SLR. This consists of adopting alternative crops that fare better under these conditions or avoiding areas too wet or saline for their desired crops. If areas are not planted with crops or tree seedlings and flood prevention measures are not in place, vegetation succession will occur and more wetland plants are expected to migrate inland (Kirwan and Gedan, 2019).

3.2.2.1. Trying alternative crops. Some producers were either interested in or were actively trying to grow alternative crops (e.g., asparagus) or salt-tolerant versions of their usual crops (e.g., soybeans). Three producers talked about their attempts at salt-tolerant crops. One producer tried asparagus (though they primarily grow grains) as well as sorghum, though the sorghum did not perform well. Another producer tried warm-season soybeans and salt-tolerant soybeans but was not pleased with their performance. A third producer was considering salt-tolerant trials from seed companies but was unable to coordinate with them in time and will consider trying to do so next year. Several producers emphasized that a new crop must work with existing machinery and have an available market.

3.2.2.2. Working around wet and salty areas. Some producers described ways in which they work around wet and salty areas. One producer said they avoid some fields in April because they know they will be too wet to plant. They wish to begin plantings early in the year, but for some areas they know they have to wait until later to allow those areas to dry out. Another producer described their desire to till the land but knew it was too wet to do so. They therefore avoided these areas for planting. Producers shared how avoiding unproductive areas can be labor intensive (e.g., moving fence lines, changing the routes of equipment for planting and harvesting). Three other producers described abandoning parts of their fields and allowing the land to go fallow. One producer described how these areas can be small and non-contiguous. Multiple times throughout the workshop and interviews, producers would express that every acre is needed to break even or bring in profit. In this regard, producers knew when not to invest in wet or saline areas unable to grow a crop—presumably from past experience or observations of flooding and saltiness. At the same time, these producers also did not invest in techniques to make the land less flooded or saline or to put the land to a different use.

3.2.3. Actions that align with directing transition

Actions consistent with "directing" change for our study are those where income is no longer generated from agriculture but rather a land use adapted to wet and saline conditions. It was beyond the purview of this study to thoroughly identify what the full suite of alternative ecological states might be; however, one scenario is the transition to tidal wetlands and the potential revenue generated from a wetland landscape, such as from conservation programs and associated recreation. Directing a landscape from agricultural production to healthy wetlands with conservation and recreational value would require active management—such as plantings, invasive species (particularly *Phragmites*) control, or topographic manipulation—rather than a passive approach to vegetation succession. For example, the USDA or state conservation programs typically require a management plan. We did not observe producers pursuing "direct" options on areas of land still viable for crop or timber production, but rather on areas already too wet and/or saline for sufficient crop yields. In several cases, producers' properties are large enough that "directing" may happen on some portion of their property while farmland further inland may persist unchanged longer into the future.

3.2.3.1. Conservation programs. Participation in conservation programs aligns with directing ecological transition because the programs listed here incentivize preservation, restoration, or creation of wetlands (i.e., a new land use) rather than farming (i.e., the current land use). Four producers mentioned participation in Farm Bill conservation programs (e.g. Conservation Reserve Enhancement Program (CREP), Conservation Reserve Program (CRP), Environmental Quality Incentives Program (EQIP)) when parts of their land were no longer productive enough to yield a profit. Yet participation in these Farm Bill programs also posed challenges for producers. Multiple producers shared that some programs required the planting of species that do not grow well under wet and salty conditions, which means producers must replant the required species when they die. Producers also described the considerable work of weed control and ditch clearing to meet CRP requirements; in some years the cost of the associated labor required may be greater than the conservation payment. Producers also considered it a disadvantage to not have as much control over farmland and shared that some agricultural easements restrict participation in conservation easements. They also described an onerous amount of paperwork involved, a slow and restrictive process, and that technical assistance was spread thin.

3.2.3.2. Hunting or other recreation. Directing farmland to transition toward biodiverse tidal wetlands allows for some wildlife-focused recreation and hunting. Several producers already allow hunting on their property. One producer described hunting as a "cash crop." In part, this speaks to the prevalence of deer and other wildlife (e.g., geese) on the land, which were often described as destructive of crops. Despite monetary benefits, producers also have concerns about allowing hunting or other types of recreation (e.g., birding) on their property. During workshop discussions, we heard concern about liability insurance coverage being necessary for recreation activities and some producers were disinclined to take that on. Given other demands on the property, some feel managing land for recreation is an additional task beyond their capacity. Additionally, smaller properties may not be suitable for recreation activities. Producers also shared that some government conservation programs have restrictions that may conflict with recreational experience.

3.3. Intentions for land management in the short- and long-term

Most survey respondents (15 out of 19) indicated that, in the short term, they plan to make efforts to protect their land from flooding (i.e., Resist) or continue managing their land as they have, accepting that some areas may become unsuitable for farming (i.e., Accept); however, in the long term, the majority of survey respondents (14 out of 19) plan to continue managing their land as they have (I.e., Accept) or transition the land to a use that is compatible with increased saltwater intrusion and flooding (i.e., Direct) (Table 4). While this response may imply a willingness or intention to move away from agriculture, during our conversations we did not hear excitement for this option. Rather, we heard strong desires to continue to farm or timber along with acknowledgement from some producers that it has been challenging to continue to grow crops on parts of their property and concern that conditions will grow worse in the future. In the following sections, we share the results of our data analysis pertaining to producers' motivations for resisting, accepting, and directing ecological change of coastal farmland.

3.4. Motivations for resisting, accepting, or directing

3.4.1. Motivations for resisting

The desire to protect farmland and woodlots from flooding and saltwater intrusion, and to drain, dry out, and desalinize already-affected areas, was expressed by many producers who participated in this project. Often going hand in hand with this expressed desire was the acknowledgement that they did not know how this could be achieved. The framing of the question, "What would you do with a blank check" versus "How are these available management options that resist change working for you?" produced significantly different responses on intention in workshop discussions. One producer half-jokingly suggested topsoil could be brought in to raise the elevation of all the farmland. Another suggested a hydrologist would have some guidance for what could be done. These calls for a way to protect their land reflects its importance to them as productive farmland. Nevertheless, they want an answer to this question: as the producer who called for a hydrologist phrased it, "Is there a way to get it back or is it just gone?" Some of the motivations for resisting saltwater intrusion and/or reclaiming flooded or salty land included:

Desire to continue to earn a living from the land. Producers wish to cultivate a profit from what they invested in their land (i.e., physical labor, cost of machinery, soil amendments, seed, etc.). Some producers want to continue applying their farmer or forester education and training and some expressed reluctance to develop other skills if they were to change their farm's land use.

Desire to preserve farmland. Producers are attached to their farmland, which has often been in the family for generations. Farming is also a part of their identity—not only for these individuals, but for the community of which they are a part. A few producers expressed they did not want agricultural land to become developed, which would erode their sense of place. Some producers went on to express they were less in it for profit (i.e., make enough to break even or pay property taxes) but instead wanted to maintain a sense of place.

Desire to achieve a vision or dream for the land. While some producers seek to maintain current operations or preserve a legacy, others are excited to newly engage in agricultural endeavors. For instance, one producer has become interested in having a winery on their property. While several of the producers have been farming for over 20 years, a few producers have recently begun farming, and in general, they shared their ambitions and intentions to keep farming. In our study there were several relatively new producers with smaller-sized farms (n = 11). Newness to farming and smaller properties, some of which were located farther inland, seemed to create a set of conditions in which producers felt optimistic and driven to resist SLR impacts.

3.4.2. Motivations for accepting

Responses in interviews and workshop discussions reveal producers were motivated to accept the changes on their land (i.e., neither resist them nor actively direct them) for several reasons.

3.4.2.1. Giving up & cutting losses. Some producers spoke with exasperation about the challenge of farming particularly wet and/or saline land. They noted trouble with machinery getting mired, the inefficiency to work around oddly shaped wet areas, fertilizer waste, and other difficulties that pose challenges for earning a profit from wet pieces of land. Therefore, these producers accepted they could no longer farm wet land. Small (i.e., less than half an acre) and noncontiguous areas needing special management (e.g., installation of tide gates) were deemed impractical to farm.

3.4.2.2. Discomfort with legal limitations. Some producers, having wet areas no longer profitably growing crops, were somewhat interested in how they might receive income from the land in other ways; yet, because they perceived such programs (such as USDA conservation programs with planting requirements) as limiting how they could use the land, they preferred to keep their options open by not enrolling in conservation programs or easements. This could allow for those areas to be used again for farming in subsequent years if conditions become more favorable (e.g., weather is suitable, new technology emerges so that crops would be productive in those areas, or some existing management techniques become less cost-prohibitive or more cost-effective).

3.4.2.3. Unfamiliar with options. Some producers accepted some areas were going to flood primarily because they did not know what else they could do to manage them profitably. Some producers believed a solution existed or could be developed but were unaware of what it might be. Other producers were aware of land management options that could potentially address the problem of flooding and high salinity, but were unaware of how they might access those options due to their perceived

Table 4
Producers' response to the post-workshop survey question, "Knowing what you do now about saltwater intrusion and flooding, which course of action are you most likely to pursue in the …"

Answer options	Make efforts to protect land from saltwater intrusion and flooding (e.g. tide gates, berms, etc.)	Continue managing your land much as you have done in the past, accepting that some patches may become unsuitable for farming	Transition the land to a use that is compatible with increased saltwater intrusion and flooding (e.g. conservation easement, hunting, carbon credits)
Analysis category within the RAD framework	Resist	Accept	Direct
Short term (over the next 5 years)	7	8	4
Long term (5 years from now and into the future)	5	2	12
Change from short to long term	11% Decrease	32% Decrease	42% Increase

high cost, whether up-front (e.g., installing a living shoreline to reduce flooding across a long length of shoreline) or over the long-term (e.g., on-going efforts required to remove invasive plants).

3.4.3. Motivations for directing

Responses in interviews and workshop discussions suggest producers would generally like to keep as much land in production as possible but could potentially be open to directed landscape transition if the outcome allowed them to maintain some income, control, and a sense of pride in their land.

3.4.3.1. Financial gain. Some producers may be open to directed change if the outcome helped to support them financially. Producers already participating in "direct" actions—primarily conservation programs such as the USDA CRP which removes environmentally sensitive land from agricultural production to help improve water quality and wildlife habitat (e.g., healthy, biodiverse wetlands)—described implementing those actions in areas no longer suitable for farming (USDA Farm Service Agency, 2022). This generates income on land not able to produce sufficient agricultural yields.

3.4.3.2. Environmental stewardship. Some producers spoke specifically of the desire to use land that could not be profitably farmed to instead contribute toward environmental goals like carbon capture, nutrient capture, or wildlife habitat. As part of their legacy on the land, some producers described their responsibilities toward protecting the environment and passing down land the next generation could take pride in.

3.4.3.3. Lack of other options. Woodlot owners indicated they would direct their woodlots to different land because resisting SLR impacts or changing to alternative crops felt infeasible on woodlots, given the longer time to harvest.

3.5. Desired future programming and research

Post-workshop survey responses also indicated what producers prioritized for future policy, research, or technical assistance (Table 5). Producers were highly interested in developing new products, programs, or improved technology to better manage for SLR impacts (e.g., cost-effective drainage options, carbon credit programs, erosion control options) and better assessment of land conditions (e.g., mapping saltwater intrusion).

Table 5
Objectives for Future Programming and Research to Address Concerns of Coastal Producers. Objectives were identified during analysis of the project pre-survey, interviews, and workshops. In the post-workshop survey, participants (n = 18) were asked to select their top three objectives. The "votes for most important" column shows the proportion of respondents who selected each objective as one of their top three. We also indicate whether each objective aligns most with resisting (R), accepting (A), or directing (D) the trajectory of the ecosystem change (see also Table 2).

Objectives for Future Programming and Research	Votes for Most Important (%)	RAD Alignment
Developing cost-effective drainage options to reduce flooding	40%	R
Mapping current and forecasted saltwater intrusion areas	35%	R, D
Developing carbon credit/carbon sequestration programs and markets	30%	R, A, D
Developing new markets for alternative, salt-tolerant crops (e.g. switchgrass, salt hay)	25%	A
Developing more affordable erosion control options	25%	R
Increasing the flexibility of plant cover required for CRP/CREP lands affected by increased water and/or salt	20%	D
Addressing destructive wildlife (e.g. beavers, deer)	20%	R
Increasing availability of technical service providers to be able to respond to concerns in a more timely manner	20%	R, D
Investigating new ways to manage *Phragmites*	20%	R, D
Increasing local markets and processing operations for timber	20%	R
Coordinating coastal mitigation strategies (e.g. drainage, *Phragmites* control) on neighboring lands	15%	R, D
Increasing access to information on water issues	10%	R, A, D
Improving salt- and water-tolerant crop performance	10%	A
Exploring alternative business ventures (e.g. ecotourism, hunting) for unproductive farmland	10%	D
Developing tools to compare the costs and benefits of various management options	5%	R, A, D
Finding alternative uses for woodlots and/or ghost forests	5%	A, D

4. Discussion

4.1. Application of the RAD framework for considering alternative adaptation options on private land

Our use of the RAD framework in this study differs from its previous application in notable ways. Foremost, the RAD framework has traditionally been used as a decision-making tool for federal land managers, while we applied the framework to consider management of private land. Private land managers (i.e., farmers or woodlot managers) have different goals, time scales, and motivations from public land managers. Public land managers may more highly consider institutional goals, key stakeholders, data availability, or management plan development (Thompson et al., 2021). While both public and private land managers must consider the costs of implementing any management strategy, public land managers may not be constrained by the further complication of making the land generate income. Another distinction is that federal land managers often manage large tracts of public land, while coastal producers have smaller landholdings, which makes decisions to resist, accept, or direct dependent in some part on what their neighbors decide to do.

Though our use of the RAD framework differs from its previous application, we nevertheless found it useful for analyzing producers' actions in response to SLR-induced land change over time. The variety of motivations and types of actions we found among producers for responding to the impacts of SLR reflects the complex challenges a land manager encounters when navigating ecological transition. While previous research on the Chesapeake Bay (Saacke Blunk et al., 2020; Tully et al., 2019b; MDP, 2019; Jacobs, 2020) has identified available adaptation options and the ecological effects of implementing those strategies, ecological impact is not the sole factor for motivating land managers' adoption of a particular adaptation strategy (Field et al., 2017). Rather, many factors (e.g., internal, external, social, cultural, and institutional) influence how to choose a particular management option from a range plausible alternatives (Clifford et al., 2022).

Coastal producers in our study considered several factors when considering whether to employ an adaptation strategy that aligns with resisting, accepting, or directing the landscape transformation caused by SLR. These included economics (i.e., earning a living, cutting losses, or taking advantage of new opportunities for financial gain), preservation of a way of life (i.e., preserving farmland, local ecosystems, or the freedom to make decisions about how the land is managed), and imagined possibilities (i.e., envisioning a specific future for the land, feeling uncertainty about possible options, or believing there is a lack of options). Other studies of coastal producers have found similar themes. For example, Akanda and Howlader (2015) also found that economics (particularly family income) and imagined possibilities (specifically awareness of different management options) influenced the adaptation strategies used by coastal farmers in Bangladesh. Similarly, the relevance of preserving a way of life is supported by the work of Pollnac and Poggie (2008), who found that some marine fishermen resist leaving the industry even when it would be economically advantageous for them to do so because the risky nature of the job brings happiness to those for whom it is well-suited. Agriculture may be similar to marine fishing in the way in which producers value the nature of the work itself. Farming not only provides a livelihood but can create a deep connection to land—often farmland can stay in the family for generations and producers may take personal pride in stewarding farmland which represents the family and community heritage.

The impacts from SLR would have to be substantial and alternatives to agriculture practices effective, efficient, and low risk for most producers to change to a different land use. While most producers in our study indicated they would transition their land to a use more compatible with flooding and saltwater intrusion in the long term, it is also important to note that not all producers moved toward this transitioning between the short and long term. Some chose the same approach in both time frames and one producer transferred from "accept" in the short term to "resist" in the long term. Schuurman et al. (2020) note that RAD management choices can be used simultaneously at a site and that a manager may shift approaches over time. An example of this within our study could be a producer putting a portion of their land into a conservation easements (i.e., direct), while allowing changes occurring in their woodlot (i.e., accept), and installing a tide gate (i.e., resist) at another section of their property. With multiple options available to producers, their land use decisions depend not only on the extent, severity, and imminence of the threat but also on long-term goals for their managed property.

4.2. Research, policy, and programming recommendations

While our study was limited to producers in coastal Maryland and Virginia, the insights gained may help to inform research, policy, and programming to better support coastal producers along the entire Mid-Atlantic region of the United States. Overall, our findings suggest that producers need further assistance as they choose to resist, accept, or direct the changes to the coastal landscape. In particular, producers indicated they need more support for resisting these changes until they may be ready to accept or direct them. The top-ranked objective for future programming and research was to improve cost-effective drainage options (see Table 5), which seems to indicate that if these options existed, producers would opt to resist changes to their landscape and continue farming or forestry. Along those lines, if conditions are wetter and/or saltier, many would continue farming if alternative flood- and salt-tolerant crops and subsequent markets were available. More research dedicated to flood- and salt-tolerant crops is needed and should include consideration of equipment needs and available markets.

Helping producers assess their current and future vulnerabilities is an important first step in supporting their successful response to the impacts of SLR. Producers were highly interested in better assessment of land conditions (e.g., mapping saltwater intrusion) and the development of new products, programs, or improved technology to better manage for SLR impacts (e.g., cost-effective drainage options, carbon credit programs, erosion control options). Efforts to address the lack of information or programming dedicated to tidal flooding or hydrology, as discussed above, could also help to support producers. A possible approach may be to establish informational channels between oceanographers, hydrologists, soil chemists, and the agricultural network (i.e., local NRCS office, Soil and Water Conservation Districts, University Extension, Farm Bureau). Support for improved soil testing may also help producers and agricultural service providers better gauge the changing conditions of coastal farmland.

Facilitating transition also involves designating when thresholds have been reached and providing an impetus to act. One suggestion expressed by a researcher at the workshop was to have an assistance program to help pay for a tide gate with the understanding that when the tide gate fails due to seawater overtopping the structure, the affected lands would then transition to wetlands or a non-agricultural use. In some cases, producers expressed there were areas they knew should probably be put in an easement or conservation program, but they had not yet done so. If greater incentives could be put in place and the process made simpler (i.e., streamlining paperwork, hiring more staff, greater resources dedicated to the conservation programs), then perhaps there would be greater participation. Even so, the degree of criticism producers shared on the incompatibility of required conservation easement plantings with wet and saline soils suggests policymakers consider revising the required plantings. A closer look may also be necessary for weed control (i.e., are the designated "weeds" still providing ecosystem services? Is the recolonization rate so high removal appears futile?). One other challenge is creating solutions for small parcels or small, noncontiguous patches on properties where management options such as alternative crops, agritourism/recreation, or easements may feel impractical. If policymakers or other conservation entities desire more wetland conservation, they must reduce the "headache" or maintenance costs that can dissuade potential participants.

Finally, producers discussed and expressed some interest in carbon markets. At the time of the study, there were no state-established, active carbon markets in the area (Maryland Manual On-line, 2022a; Virginia Department of Environmental Quality). Since it is unknown if participating in a carbon market would require a transition away from agriculture, we did not include it in our RAD analysis. One producer expressed hope to have a crop with market value as well as the ability to generate carbon credits for carbon sequestration. Woodlot managers seemed excited at the prospect of having their property valued in a new way—though further discussion is necessary with carbon market experts to determine how a transition from coastal forest to tidal wetland would be valued. A few producers expressed concern over the regulations and bureaucracy associated with participation in a carbon market. Overall, producers desired further information and saw potential for participation.

4.3. Study limitations

Due to COVID-19 safety precautions, our project team hosted the workshops virtually rather than in-person, which required workshop participants to have a reliable phone or internet connection and functional knowledge of the Zoom virtual meeting platform. A few potential participants expressed poor connectivity in their area and were unable to participate; however, other participants expressed preference to meet virtually, citing greater convenience. In the post-workshop survey, producers indicated that overall they found the workshop design to be "very effective." The level of strong engagement and candor we had during this workshop, given COVID-19 stresses and the need for virtual meetings, highlights how important producers view this issue.

While this study explored coastal producers' actions and motivations for resisting, accepting, and directing coastal land transition, we cannot say the extent to which these actions and motivations are relevant to coastal producers outside of our study due to our small and non-probabilistic sample. However, this study lays the groundwork on which future studies could build to explore the distribution of these identified actions and motivations by engaging a larger number of producers across a greater area. A possible approach to follow-up on this study would be to identify tax parcels within agricultural areas at risk of inundation to develop a random sample of landowners potentially affected by SLR (see Jacobs, 2020).

5. Conclusion

Coastal agricultural lands will be increasingly exposed to wetter and saltier conditions as sea level rises. While numerous studies have examined the potential extent and impact of SLR on local ecosystems and agricultural production, relatively little attention has been given to how coastal producers are making land management decisions within the context of SLR. This exploratory study sought to better understand the factors that coastal producers take into consideration as they respond to and prepare for wetter and saltier soils. Specifically, we explored what impacts from SLR coastal producers are observing on their land and how these and other factors influence land management decisions. We used the RAD framework as an analytical frame to categorize producers' intended responses to SLR.

While the majority of producers in our study indicated their intention to transition the land to a use that is compatible with increased saltwater intrusion and flooding in the long term, this is not a transition that many of them look to with eagerness. Rather, most producers in our study would prefer to continue farming yet face a lack of effective and/or affordable management options to resist ecological changes. Our findings suggest that flexible mechanisms that support producers in resisting the impacts of SLR in the short term, while supporting them in directing the transition of their land to another productive use in the long term, may be especially beneficial. A strong partnership among coastal producers, scientists, and policymakers will best support successful adaptation of coastal producers in Maryland and Virginia as well as in other locations around the U.S. and the world where SLR is affecting agricultural production.

Credit author statement

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

The data that has been used is confidential.

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