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Adapting to Water Scarcity: Effects of Irrigation Management

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Adapting to Water Scarcity: Effects of Irrigation Management and Psychological Factors on Crop Productivity

by

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Abstract

In developing countries, farmers are dealing with climatic changes by adapting their agricultural practices. Little work has investigated the direct impact of structural variables (e.g., central vs. local management of irrigation water, location of village), psychological variables (e.g., risk perceptions, self-efficacy), and adaptation on crop yield. We tested a psychology-based model that focused on risk perceptions and efficacy beliefs by longitudinally surveying 278 Sri Lankan rice farmers. We assessed risk perceptions and efficacy beliefs before the major paddy-growing season and measured whether farmers performed adaptations as well as their paddy yield/acre after the season. The model significantly predicted more than 25% of the variance in crop yield, with increased yields associated with centrally managed irrigation resources and with farmers low in perceived climate risk at the start of the growing season. Findings support the notion that while psychological factors are important, structural variables are the most important predictors of farm productivity in times of uncertain water supply.

Keywords: efficacy, risk perception, climate change, adaptation, common pool resources

Perceptions of Climate Change:

Predictors of Farming Success among Sri Lankan Farmers

Global climate change is a growing concern for international policymakers as it results in events such as temperature rise, sea level rise, droughts, floods, hurricanes, and landslides (IPCC, 2014). Developing countries whose governments lack the resources to combat these threats are at the most risk (Food and Agriculture Organization, 2013), and smallholder farmers who rely on agricultural production as their primary source of income are particularly vulnerable (Food and Agriculture Organization, 2013; Morton, 2007). Climate change is predicted to contribute to an increase in global malnourishment and a decline in crop production over the next century (Fischer, Shah, & Velthuizen, 2002; Lobell et al., 2008). Within South Asia, the decline in productivity is projected to leave over 250 million people malnourished by the end of the century (IPCC, 2001; Lobell et al., 2008; Murdiyarso, 2000). In light of these projections, it is of utmost importance that policymakers look for ways to ensure food security and combat the threat of climate change.

One of the main ways climate change affects food security is through extreme events such as droughts (Hulme, 1996). Drought is particularly stressful for communities that lack a well-developed irrigation supply (Rosenzweig, Tubiello, Goldberg, Mills, & Bloomfield, 2002), because it constrains water supplies and can lead to a reduction in crop yield (Rosenzweig et al., 2002). For example, in 2002, a drought in India affected over half the country and caused rice production to decline by 20% from its typical yield (Pandey et al., 2006). Hence, policymakers in developing countries, that lack well-developed irrigation supply, must emphasize the importance of developing successful climate change adaptation measures (Burton, 2001). Adaptation is a response to an actual or perceived threat that seeks to moderate or remove the threat (IPCC, 2014). Specific adaptations called upon to combat the threat of drought-related water and food shortages include water infrastructure and reservoir development, adaptive water resource management, improved agricultural practices, and irrigation management (IPCC, 2014). Potential barriers to institutional level adaptation can be economic constraints, political and social limits, and capability of irrigation management agencies (IPCC, 2007).

Successful adaptation must reduce risk and vulnerability associated with the threat (Pielke, 1998). Regarding farming, adaptations can be responses made in direct response to a consequence of a threat, such as buying crop insurance after experiencing a drought. Adaptations can also be protective measures, taken in anticipation of a threat such as planting a less water-intensive seed when expecting a water shortage. Protective measures are sometimes preferred because farmers who take protective measures in an attempt to account for future changes in climate have the ability to ease the impact of climate change (Mendelsohn & Dinar, 1999).

Successful adaptation to climate change should lead to an increase in crop yield (Pretty et al., 2006; Rockström et al., 2009). According to the Intergovernmental Panel on Climate Change (IPCC) agricultural production is expected to decrease across South Asia and adaptation is necessary to combat this threat (IPCC, 2007). A meta-analysis of crop stimulation studies suggests that crop-level adaptations increase rice productivity by 7-15% (Challinor et al., 2014). Additionally, in the face of water shortages, agricultural adaptations including water efficient crop varieties, supplemental irrigation in rain-fed areas, and adopting conservation farming techniques have been shown to lead to an increase in crop yield (Pretty et al., 2006; Rockström et al., 2009). However, some studies suggest the short-term benefits of adopting new farming methods are mixed (Liu, 2008; Rusinamhodzi et al., 2011). Rusinamhodzi et al.'s (2011) meta-analysis suggested that farmers who continued to use a new adaptation technique reported an increase in yield over time. However, the increase in crop yield may not be initially noticeable with a possibility of an initial decline in yield when first trying a new technique, likely due to a learning curve (Rusinamhodzi et al., 2011).

Common Pool Resources

Common-pool resources (CPRs) are natural or human-made resource systems (e.g., irrigation systems) that generate a set amount of resource units (e.g., water). When resource users subtract resource units from the system, it subtracts the amount available to other users (Ostrom, Gardner, & Walker, 1994). The tragedy of the commons occurs when individuals make short-sighted decisions based on prioritizing their short-term self-interests over the collective interest of the community (Hardin, 1968).

Communities that successfully manage their irrigation supply can enhance the efficacy of crop production (FAO, 1997). Ineffectively managed irrigation systems often waste resources, resulting in lower crop yields (FAO, 1997). Governance systems play a significant role in the sustainability of irrigation systems and lead to unique village level differences, such as the level at which resources are managed. Communities with locally managed resources often have communal property rights, where a community of interdependent users manages resources. Rights to the resource within the community are non-exclusive, and their rights often entail equal access and use (Feeny, Berkes, Mccay, & Acheson, 1990). Centrally managed villages often have state property rights, where the government makes decisions concerning access to a resource (Feeny et al., 1990).

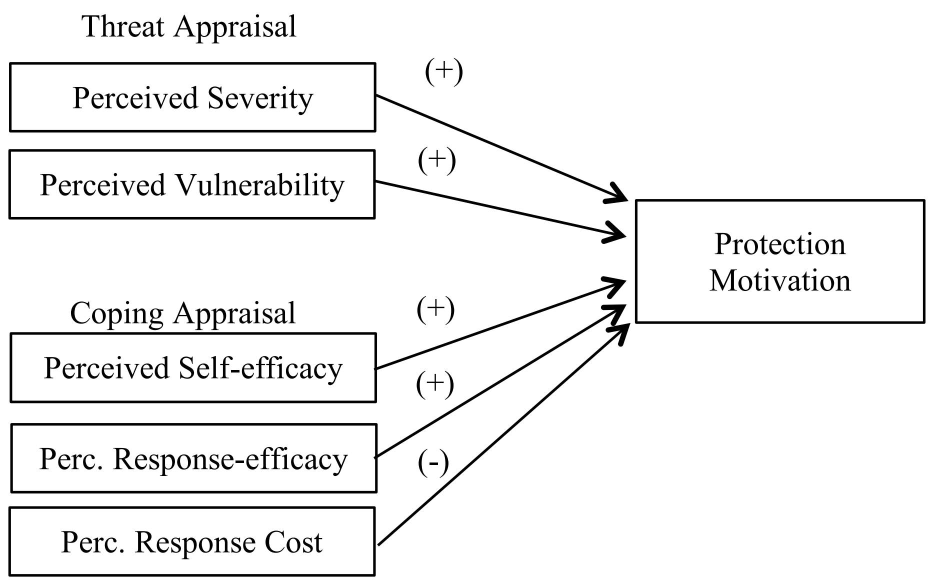
Case studies investigating the effects of decentralization of forests in Nepal and India suggest that communities with locally managed resources will be more efficient than decisions made by government authorities at the national level (Agrawal & Ostrom, 2001; Wade, 1987).

These findings have encouraged policymakers around the world to involve local communities in decision-making (FAO, 1999; Wade, 1987). Communities with locally-managed resources may have higher social capital and better access to information that directly affects the communities (Agrawal, 2003; Fiszbein, 1997b). The increase in social capital may allow communities with locally managed resources to be more efficient than those with centrally managed resources while taking collective action (Agrawal, 2003; Fiszbein, 1997b). Additionally, farmers in communities with locally managed resources are able to see a direct relationship between their investments to the resource and resource outcomes, which increases productivity (Ostrom & Hess, 2007). Low productivity occurs when there is a lack of incentive to increase an individual's investment and seek improvements through adaptations (Ostrom & Hess, 2007). After the implementation of government control in a community that previously had locally managed resources, the community often becomes less efficient (Thomson, 1977). Thus, communities who locally manage their resources should out produce centrally managed communities.

Effective Adaptation to Climate Risk: A Conceptual Framework

Previous research suggests that through successfully managing CPRs and performing adaptations, individuals can combat the detrimental effects of climate change (Agrawal & Ostrom, 2001). Meanwhile, psychological variables have been predictive of performance of adaptive behavior (Esham & Garforth, 2013; Grothmann & Patt, 2005; Truelove, Carrico, & Thabrew, 2015). This study expanded upon a growing body of literature examining the importance of psychological factors in influencing the adoption of adaptation behaviors. In particular, we investigated how the psychological factors of risk perception and self-efficacy influence farming productivity (Esham & Garforth, 2013; Grothmann & Patt, 2005; Truelove et al., 2015).

Protection Motivation Theory. Protection Motivation Theory (PMT; Figure 1) seeks to explain the effect that fear appeals have on an individual's attitude change (Rogers, 1975). A fear appeal is typically a message designed to promote behavior change by instilling fear in participants. Fear appeals are thought to be mediated by four cognitive components: severity and probability of a depicted event (risk perception), efficacy of a coping response (response efficacy), and ability to effectively respond to a threat (self-efficacy) (Rogers, 1975).



Note: +/- Hypothesized direction of relationship

Figure 1. Conceptual model of Protection Motivation Theory (Rogers, 1975)

Risk perception, the perceived likelihood of a threat occurring, is one of the central tenets of PMT (Rogers, 1975). An individual's risk perception impacts the likelihood that he or she will respond to a threat (Cutter & Barnes, 1982; Drabek, 1969). Another component of PMT is self-efficacy, the internal belief that one is capable of successfully performing a behavior regardless of skill level (Bandura, 1977, 1988). Self-efficacy influences the amount of effort an individual exerts on a task, their perseverance, and their ability to bounce back after suffering setbacks (Bandura, 1988). When someone has low self-efficacy, the individual may not see a point in exerting effort to control his or her behavior, which can lead to poor work performance and maladaptive behaviors (Bandura, 1988). Self-efficacy is instilled through successful experiences, where previous success strengthens the perceived belief in one's capabilities (Bandura, 1988). However, during times of emotional stress or arousal, self-efficacy can be lowered (Bandura & Adams, 1977). For instance, in times of drought, an individual's belief that he or she is capable of dealing with a stressful situation may be lowered.

According to PMT, farmers will undertake protective action when they perceive that drought will occur or they view themselves as capable of dealing with the drought. Consequently, a farmer with low self-efficacy may engage in an alternative behavior, which may momentarily remove the threat by lowering the individual's perceived fear (Rippetoe & Rogers, 1987).

Grothmann and Patt (2005) expanded upon PMT and developed a socio-cognitive Model of Private Proactive Adaptation to Climate Change (MPPACC) . The MPPACC (Figure 2) explains what psychological processes underlie an individual's adaptation to climate change effects (e.g., drought, flood, storm). The MPPACC separates the psychological processes in the model from socio-structural factors (i.e., location, demographics). The MPPACC has been predictive of adaptive behavior above a strictly socio-structural model (e.g., demographics, location, income) (Esham & Garforth, 2013; Grothmann & Patt, 2005; Truelove et al., 2015).

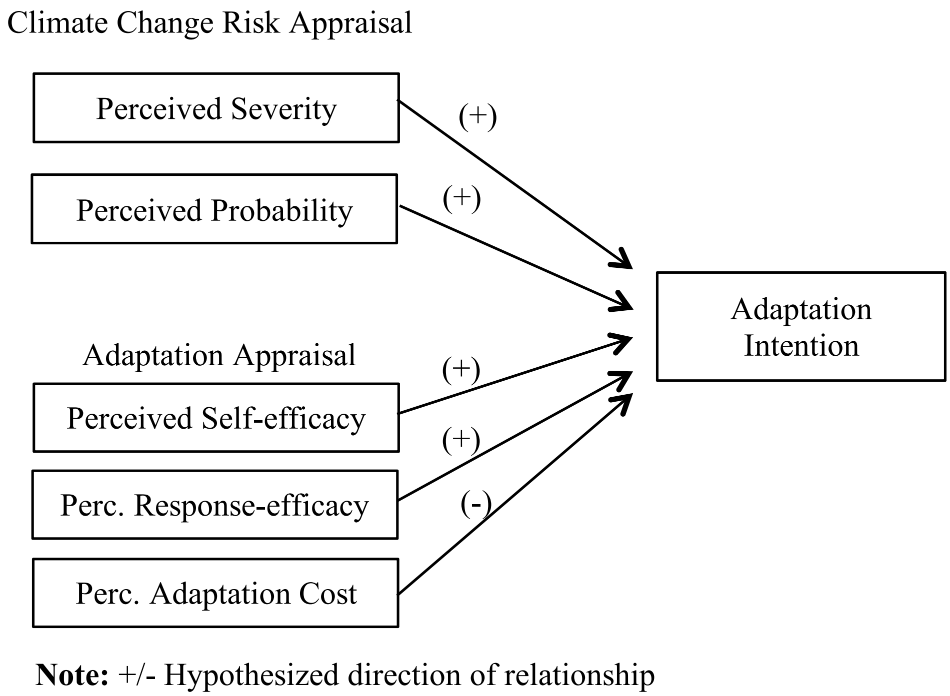


Figure 2. Conceptual model of Private Proactive Adaptation to Climate Change (Grothmann & Patt, 2005)

Individual components of PMT (i.e., efficacy and risk perception) are predictive of adaptive responses to climate change (Esham & Garforth, 2013; Truelove et al., 2015). Farmers must perceive that changes in the climate are taking place in order to adapt (Bryan, Deressa, Gbetibouo, & Ringler, 2009; Deressa, Hassan, Ringler, Alemu, & Yesuf, 2008). Risk perception has been linked to adaptive response when adapting to climate change threats such as droughts (Ishaya & Abaje, 2008; Mertz, Mbow, Reenberg, & Diouf, 2009; Patt & Schroter, 2008). Individuals who have been previously affected by climate change are more likely to perceive a threat of future climate change and take protective action (Whitmarsh, 2008). Specifically, individuals who previously experienced air pollution were more likely to take environmentally-specific actions in response to the threat (Bord, O'Connor, & Fisher, 2000; Whitmarsh, 2008). Farmers with higher efficacy were also more likely to adapt during times of weather uncertainty and to plant a wider variety of crops (Roy, 2009). Furthermore, farmers who perceived they successfully adapted to climate change using a particular adaptation were more likely to intend to use that technique in the future (Truelove et al., 2015). Regarding drought, individuals who perceived a threat and had higher efficacy were more likely to show an intention to adapt in the future (Grothmann & Patt, 2005).

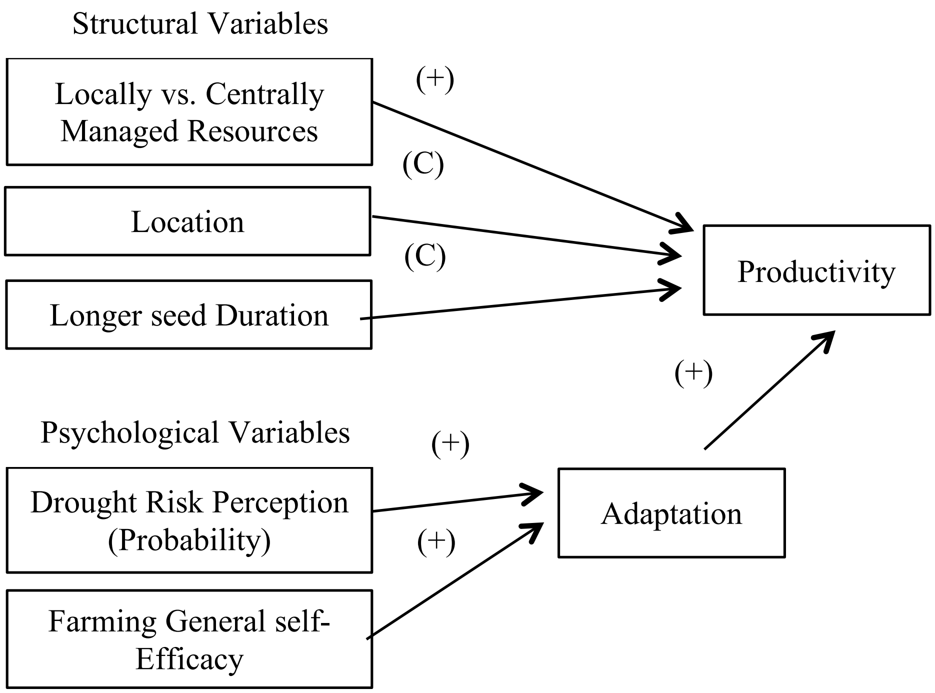
While PMT-based models as a whole, as well as the components of PMT (efficacy and risk perception) have been predictive of adaptation (Deressa et al., 2008; Esham & Garforth, 2013; Roy, 2009; Truelove et al., 2015), no research using a PMT-based model has predicted the actual success of adaptation, such as a farmer's rice production. Measuring actual productivity allows us to use PMT to test actual success and not just intention to adapt or adaptation behavior. Theoretically, PMT should be predictive of farmers' actual yield because increased adaptation to climate change relates to higher yields (Pretty et al., 2006; Rockström et al., 2009).

Current Study

The current study investigated the roles that structural factors (irrigation management, location, seed duration), psychological factors (efficacy, risk perception) and adaptation have on actual farming productivity (paddy yield/acre). Previous research has suggested that adaptation and structural factors such as mangement of CPRs influence productivity (Agrawal & Ostrom, 2001; Wade, 1987). Additionally, the location of the village (which can be used as a proxy of rainfall in an area) and growth duration of the paddy seed planted should relate to yield (De Silva, Weatherhead, Knox, & Rodriguez-Diaz, 2007; Vergara, Tanaka, Lilis, & Puranabhavung, 1966). Finally, psychological factors influence an individual's ability to adapt to a climate change threat (Esham & Garforth, 2013; Ostrom, 2009).

We aimed to expand on previous research and create a model that would be predictive of actual productivity (Figure 3). Predicting farm productivity would allow us to test whether a

PMT-model is predictive of actual success, not just intention to adapt. Additionally, this model would allow us to compare the role that psychological factors have on productivity compared to stuctural factors.



Note: +/- Hypothesized direction of relationship; C = Control Variable

*Figure 3.*Conceptual model of hypothesized model predicting productivity

H1. Communities with locally managed irrigation resources will have greater paddy yield/acre than communities with centrally managed resources.

H2. Psychological variables (i.e., self-efficacy and risk perception) of the PMT-based model will account for more variation in paddy yield/acre than a strictly structural model.

H3. Farmers who have higher farming self- efficacy and/or perceived likelihood of future drought will have significantly greater crop yield/acre.

H4: Farmers who perform an agricultural adaptation technique will have significantly greater crop yield/acre.

Method

Study Area

Sri Lanka, which is classified as a *vulnerable small island nation,* was chosen for this study due to its reliance on agriculture, its vulnerability to drought risk*,* its unique village-level government differences and recent farmer relocation program, and a paddy growing season which naturally provides a point during which adaptation is necessary (De Silva et al., 2007; Murray & Little, 2000). In Sri Lanka, paddy is one of the predominant field crops grown for local consumption (De Silva et al., 2007), with approximately 800,000 farmers and their families' livelihoods depending directly on paddy production (De Silva et al., 2007).

Successful paddy cultivation is highly susceptible to uncertainty of rainfall and irrigation water received during the major growing season, Maha, which falls between October-February, though exact dates are regionally dependent (De Silva et al., 2007). Recent climate studies indicate that the amount of rainfall received in Sri Lanka has been gradually declining leading to growing concern over water security (Jayawardene, Sonnadara, & Jayewardene, 2005). Of utmost concern is the decline in rainfall during Maha (De Silva et al., 2007), because paddy is a water-intensive crop and reduction of rainfall can result in crop failure and decreased yield (Esham & Garforth, 2013).

The Sri Lankan government established the Mahaweli Project in 1969 in an effort to increase agricultural productivity, provide widespread food security, and relocate landless villagers (Jayewardene, n.d.; Mahaweli Authority of Sri Lanka, 2013). As a result, more than 100,000 people have been and continue to be resettled from overpopulated communities into unsettled areas within the dry zone of Sri Lanka (Mahaweli Authority of Sri Lanka, 2013). Resettled communities within Sri Lanka are organized by resettlement systems, which are named by letters ranging from Mahaweli System A to Mahaweli System M. Each of these systems is comprised of many different villages.

Resettlement has led to a changing composition of communities and unique differences in irrigation decision-making within the dry zone (Murray & Little, 2000). Within Sri Lanka, irrigation water is managed either centrally by the Irrigation Department (ID) or the Mahaweli Authority-Sri Lanka (MA-SL) (government control) or locally by farmer organizations (village level control). Resettled villages, which are centrally managed, are under the jurisdiction of either the ID or the MA-SL. The Mahaweli River Watershed (MRW) plays an integral role in providing water security for centrally managed villages within the agricultural dry zone (Murray & Little, 2000). The MRW is continually being diverted as part of the Mahaweli project to provide a reliable irrigation supply for these villagers. Approximately 60% of all water resources available in the Mahaweli basin is diverted into areas within the dry zone (Mahaweli Authority of Sri Lanka, 2013). On the contrary, traditional villages consist of families who were already living in the region prior to the resettlement. Traditional villages are locally managed, where their irrigation supply is not supplemented by the Mahaweli Project but instead consists of a system of small-scale canals and tanks not connected to the Mahaweli Project canal system (Murray & Little, 2000).

Site Selection

Six communities were chosen for inclusion in this study from within the dry zone of Sri Lanka. All six communities were selected at the *Grama Niladhari* (GN) division level, classified as the smallest administrative unit in Sri Lanka. Each GN typically consists of one or two large villages or several small villages (Table 1).

Table 1.
Summary of background of selected sites

Village	Irrigation Type	Divisional Secretariats	System
Kekirawa-CM	Centrally Managed	Kekirawa	H upstream
Kekirawa-LM	Locally Managed	Kekirawa	H upstream
Thalawa-CM	Centrally Managed	Thalawa	H downstream
Thalawa-LM	Locally Managed	Thalawa	H downstream
Medirigiriya-CM	Centrally Managed	Medirigiriya	D1
Medirigiriya-LM	Locally Managed	Medirigiriya	D1

We purposively selected two Mahaweli systems, H and D1, in which to focus our study due to their location in the Mahaweli River Watershed. We chose three divisional secretariats (DS), which are larger administrative subunits than GNs. Two DSs were selected in System H, one upstream and one downstream and one was selected in D1. We randomly selected two matched GNs (one-locally managed, one-centrally managed) from each of the three DSs. Selection of GNs occurred via a random number generator, where we selected one alternate site within each DS. Matching communities enabled us to have a more representative sample of the dry region of Sri Lanka and to control for political and geographic differences within the region. All villages sampled were located in the agricultural dry zone (Figure 4) where paddy is the primary crop produced (Withanachchi, Köpke, Withanachchi, Pathiranage, & Ploeger, 2014).

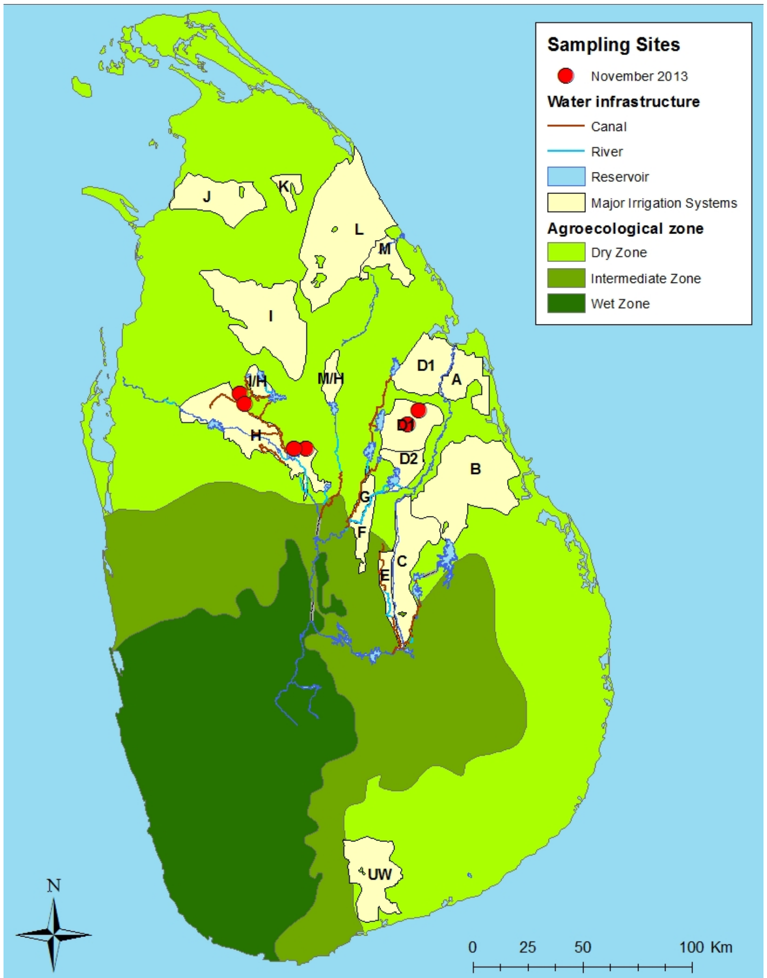


Figure 4. Map of Sri Lanka demonstrating the six research sites relative to the rainfall zones and major irrigation systems.

Participant Selection

A sample of 278 farmers was randomly selected from the six villages from a farmer registrar kept by the GN officers and farmer organization heads. At each household, the respondent was asked whether he was the primary decision-maker for farming-related decisions. If the head of household was not present, the interviewers attempted to locate him or her on their nearby paddy land. If the farmer was unable to be located, the interviewer skipped the household and moved to the next household. The head of the household was typically male (80%). Farmers ranged in age from 21 to 85 years old, M = 49.87 years, SD = 12.84. The majority of farmers had education greater than secondary education (78.4%) and were predominantly Sinhalese Buddhist (99.6%). Farmers in this region were typically experienced, *M* = 26.05 years, *SD* = 13.16, and were predominantly full-time farmers (93%).

We compared how our household sample compared to the 2011 census data (Table 2). Our household sample generally had more persons per household than the population, according to the census data. Additionally, farmers in our sample had a lower proportion of children under 15 than the general population according to the census data.

Table 2.

Demographic profile of household sample compared to the 2011 census data.

	Potanegama		Mailagaswewa		Kurunduwewa		Moragoda		Wijayapura		Wadigawewa	
	Sample	Census	Sample	Census	Sample	Census	Sample	Census	Sample	Census	Sample	Census
Population		1716		732		1875		1769		947		1226
Households	64 (13%)	479	30 (16%)	193	46 (9%)	512	46 (9%)	495	46 (16%)	283	46 (14%)	337
Persons per household	5.14	3.60	4.70	3.80	5.35	3.66	4.87	3.56	4.91	3.35	4.97	3.64
Gender												
% Male	46%	48%	52 %	49%	50%	49%	49%	51%	50%	51%	51%	51%
Age												
% less than 15 years	15%	28%	16%	26%	19%	28%	15%	27%	19%	28%	16%	26%
% over 60 years	12%	9%	13%	11%	9%	9%	15%	9%	15%	14%	7%	7%

Procedure

Nielsen Lanka, a survey firm that has extensive experience collecting surveys throughout Sri Lanka, administered the survey to the head of household. The interviewers administered two structured face-to-face interview sessions each lasting approximately sixty minutes. The interviewers administered the first survey before the start of the Maha growing season (November 2013) and the follow-up survey at the conclusion of the Maha growing season (April 2014). Collecting data both before and after Maha allowed us to assess the influence that management of irrigation and psychological predictors before the season have on actual rice productivity.

Measures

The survey instrument was developed in consultation with colleagues at the National Building Research Organization (NBRO), Sri Lanka, and other local officials. The survey was written in English, translated into Sinhalese, and then back-translated into English to check for inconsistencies. Focus groups and pilot field-testing were conducted to create appropriate measures for the survey (Table 3).

Table 3

Survey items and recoded items with response options.

Survey Items		Recoded Variable	
Question	Response Options	Question	Response Options
Seed Duration Item		**Seed Duration Item**	
What paddy seed duration did you plant last Maha (enter durations in months)?	Open ended	"Same"	
Drought Risk Perception Items		**Drought Risk Perception Items**	
In the next 5 years, do you think the amount water received for irrigation will increase, decrease, or not change	1 = Decrease 2 = No Change 3 = Increase 4 = Don't know/ can't say	Drought Risk Perception (Very Low vs High)	1 = Very Low (Responded "Decrease" to zero drought risk perception items) 2 = Low (Responded "Decrease" to one drought risk perception items) 3 = Medium (Responded "Decrease" to two drought risk perception items) 4 = High (Responded "Decrease" to three drought risk perception items)
In the next 5 years, do you think the amount of Maha rainfall will increase, decrease, or not change	1 = Decrease 2 = No Change 3 = Increase 4 = Don't know/ can't say		
In the next 5 years, do you think the frequency of drought will increase, decrease, or not change	1 = Decrease 2 = No Change 3 = Increase 4 = Don't know/ can't say		
General Farming Efficacy Items		**General Farming Efficacy Items**	
I am a good farmer	1 = Strongly disagree 2 = Agree to certain extent 3 = Strongly agree	Efficacy High vs Low	0 = Low (Other) 1 = High (Responded "Strongly agree" to at least two general farming efficacy items)
I have control over my farming yield	1 = Strongly disagree 2 = Agree to certain extent 3 = Strongly agree		
I am able to adapt my agricultural practices to changing weather patterns	1 = Strongly disagree 2 = Agree to certain extent 3 = Strongly agree		
Adaptation Items		***Adaptation Item***	
Practiced Kakulan last season?	0 = No 1 = Yes	Did farmer perform any of the adaptations last Maha	0 = No 1 = Yes
Planted a drought-resistant seed variety last season	0 = No 1 = Yes		
Transplanted seedlings (vs. broadcast method) last season	0 = No 1 = Yes		
Used Saturation Irrigation last season	0 = No 1 = Yes		

Farming General Self-Efficacy. The farming general self-efficacy items were designed to measure villagers' coping appraisals. We adapted items from previous research measuring farming self-efficacy, which examined efficacy beliefs of Indian farmers (Roy, 2009). Villagers were asked to rate their efficacy on a 3-point scale ranging from "Strongly Disagree" (1) to "Strongly Agree" (3). There were three farming self-efficacy included in the survey: "I am a good farmer", "I have control over my farming yield", and "I am able to adapt my agricultural practices to changing weather patterns".

Drought Risk Perception. We created the drought risk perception items to measure villagers' beliefs about the likelihood of future water scarcity. Villagers were given a prompt, "In the next 5 years, do you think this will increase, decrease, or not change," and responded on a 4-point scale, "Decrease," "No Change, " "Increase," and "Don't Know". Three drought risk perception items were included in the survey: "Amount of rainfall during Maha," "Frequency of drought," and "Amount of water received for irrigation."

Adaptation. To measure adaptation we assessed whether the farmer used one of the adaptation methods we asked about during the 2013-14 Maha season. Villagers were given a prompt, "Practiced ___ last season?", and were asked to respond either "Yes, after December 2013" (2), "Yes before December 2013" (1) or "No" (0). The four adaptations used in this measure consisted of: "Planted a drought-resistant seed variety," "Practiced Kakulan," "Transplanted seedlings (vs. broadcast method)," and "Used Saturation Irrigation." Drought-resistant seeds are seeds that have the ability to withstand water-stressed environments (Luo, 2010; Truelove et al., 2015). Kakulan is a type of dry seedbed preparation and dry sowing (FAO, 2012). Transplanting seedlings is a widely practiced adaptation where farmers nurse seedlings in seedbeds and transplant them into the soil (Peace Corps, 1980). Transplanting seedlings allows the seedlings to have an advantage in overcoming weeds (Peace Corps, 1980). On the other hand, broadcast seeding occurs when seeds are scattered by hand across the field (Peace Corps, 1980). Finally, saturation irrigation is an irrigation technique where farmers lightly saturate fields instead of deeply flooding the fields, which requires less water (Truelove et al., 2015).

Paddy seed duration and paddy yield/acre. We measured paddy seed duration during the follow-up survey from the survey item: "What paddy seed duration did you plant last Maha (durations in months)?" We calculated the outcome measure, "paddy yield/acre," from the amount of paddy bushels cultivated per acre harvested during the Maha growing season. These items were self-report and given during the follow-up survey after the Maha growing season.

Results

Data Preparation and Descriptive Statistics

To test the effects that irrigation management, PMT, and adaptation have on paddy yield/acre, we planned to perform a four-step hierarchal linear regression in SPSS. Before testing the model, we tested whether the variables planned for inclusion met the regression assumptions. The farming self-efficacy scale failed to meet the linearity assumption (Figure 5). Therefore, we dichotomized general farming self-efficacy into two categories, high and low. We operationalized high efficacy as farmers who responded to the most efficacious response option (i.e., Strongly Agree), on at least two of the three survey items. All other responses were categorized as "Low."

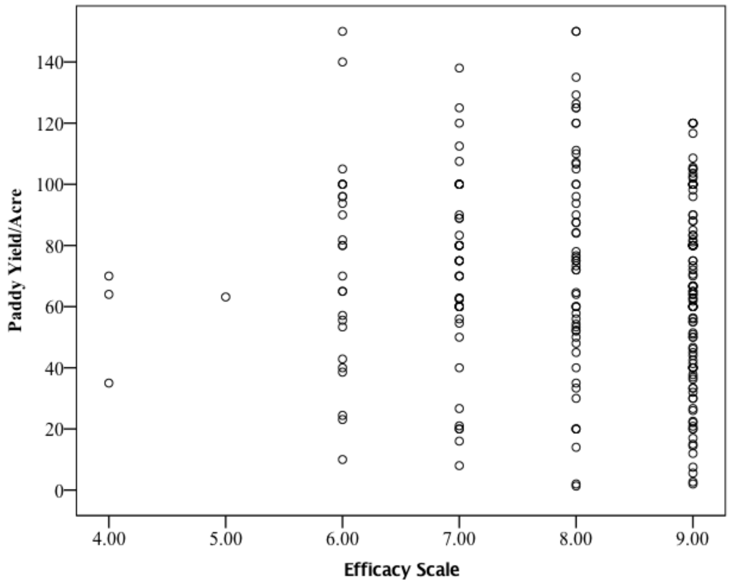


Figure 5. Scatterplot testing the linearity assumption between farming general efficacy and paddy yield/acre.

For the risk perception scale, risk perception items were first dichotomized into “Yes” or “No” questions with farmers who replied “Don’t Know”, “Increase”, or “No Change” coded as “No” and farmers who replied “Decrease” coded as “Yes”. For the item “In the next 5 years, do you think the frequency of drought will increase, decrease, or not change?” we counted “increase” as a “yes”. We summed the responses to the three risk perceptions in an effort to create the Drought Risk Perception scale. Higher levels of drought risk perception indicated farmers viewed the likelihood of climate risks to be increasing. However, the scale failed to meet the linearity assumption of the regression. Therefore, we dummy coded the risk perception score treating those who responded “yes” to all three items as the reference category “High”.

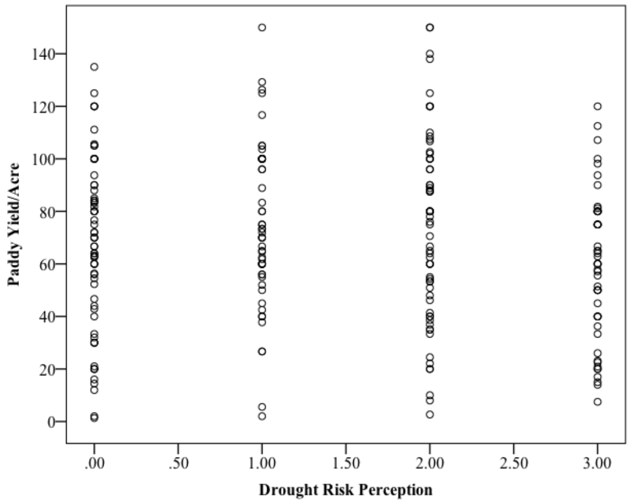


Figure 6. Scatterplot testing the linearity assumption between drought risk perception and paddy yield/acre.

For the adaptation items, we initially sought to create a sum score of the four items. However, given the skewed distribution of the adaptation sum score (z-score = 10.50, $p < .001$), we created a new adaptation measure. The new measure was “Did you perform an adaptation last Maha?” For a complete list of the measures included in the regression and their descriptive statistics, see Table 4.

Table 4

Descriptive statistics of survey items (n=233)

Measure	*M*	*SD*	%
Paddy Yield/Acre	68.84	32.35	-
Paddy Seed Duration (months)	3.49	0.34	-
Irrigation Structure			
Centrally Managed	-	-	59
Locally Managed	-	-	41
Location (DS)			
Thalawa	-	-	33
Kekirawa	-	-	30
Medirigiriya	-	-	37
Efficacy			
High	-	-	68
Low	-	-	32
Risk Perception			
Very Low	-	-	29
Low	-	-	22

Medium	-	-	27
High	-	-	22
Performed Adaptation last Maha (Yes)	-	-	13

Comparing Differences in Irrigation Structure

To better describe the data, we conducted t-tests and chi-square analyses to compare the differences in the survey items by irrigation structure (Table 5). There was no difference in whether someone performed an adaptation between communities of different irrigation structure except for whether they practiced Kakulan last Maha. Farmers in communities with locally managed irrigation were significantly more likely to use Kakulan than those in communities with locally managed irrigation (X^2 (1, N = 278) = 5.14, p =.031).

Table 5.

Descriptive statistics of survey items of full sample and irrigation structure subsamples

	Centrally Managed	Locally Managed	Full Sample
Variables	M (SD)	M (SD)	M (SD)
General Farming Self-Efficacy			
I am a good farmer	2.53 (.52)	2.53 (.51)	2.53 (.52)
I have control over my farming yield	2.58 (.54)	2.59 (.51)	2.59 (.52)
I am able to adapt my agricultural practices to changing weather patterns	2.43 (.55)	2.49 (.55)	2.47 (.56)
Paddy Seed Duration planted last Maha (months)	3.54 (.32)	3.33 (.34)	3.45 (.34)
	%	%	%
Drought Risk Perception			
Decrease Maha Rain	48%	58%	53%
Decrease Irrigation Water	41%	48%	44%
Increase in Drought	40%	43%	42%
Adaptations(Practiced last Maha)			

Kakulan	7 %	16%	11%
Drought-resistant seed	19%	25%	21%
Transplanted Seedlings	5%	7%	6%
Saturation Irrigation	6%	2%	4%

Correlations

We conducted correlations to investigate relationships between the items included in the regression analysis (Table 6). Depending on the data type of the variables, we conducted the following correlations; Pearson (two continuous measures), Point Biserial (dichotomous and continuous variables), Biserial (ordered dichotomous and continuous variables), and Phi (two categorical variables) for our analyses. Paddy yield/acre was positively associated with seed duration and centrally managed communities, and negatively associated with living in Kekirawa. Lower efficacy was associated with individuals living in Thalawa. Additionally, villagers in centrally managed communities were less likely to perform an adaptation.

Table 6.

Correlations between Survey Items Included in Regression

Measures	1	2	3	4	5	6	7	8	9	10
1.Paddy Yield/Acre	1	$.26^{**}$	-.07	-.02	.09	.09	-.08	$.20^{**}$	$-.27^{**}$	-.09
2.Seed Duration	--	1	.05	-.12	$.11^{+}$	.09	-.08	$.29^{**}$	$.20^{**}$	$-.20^{**}$
3.Efficacy High vs Low	--	--	1	-.09	.05	.01	-.01	.06	.04	$-.13^{*}$
4. Drought Risk Perception (Very low vs High)	--	--	--	1	$-.35^{**}$	$-.40^{**}$	-.04	-.01	.02	$.24^{**}$
5. Drought Risk Perception (Low vs High)	--	--	--	--	1	$-.33^{**}$	-.05	$.13^{*}$	-.02	.12*
6. Drought Risk Perception (Medium vs High)	--	--	--	--	--	1	.08	.01	.03	$-.20^{**}$
7. Adaptation (Yes vs No)	--	--	--	--	--	--	1	$-.17^{**}$	$-.11^{+}$	.04
8. Centrally Managed vs Locally Managed	--	--	--	--	--	--	--	1	$.17^{**}$	-.09
9. Kekirawa vs. Medirigiriya	--	--	--	--	--	--	--	--	1	$-.50^{**}$
10. Thalawa vs. Medirigiriya	--	--	--	--	--	--	--	--	--	1

**Note $^{+}p<.10$, $*p<.05$, $**p<.01$*

Regressions

A four step hierarchical linear regression was conducted with structural (irrigation management type, village location (DS), and seed duration), psychological (efficacy and risk perception), and adaptation predicting farmers' rice yield per acre (Table 7). Forty-four farmers did not harvest during the Maha season and one farmer was not available for the follow-up interview. Therefore, the regression analysis included 233 farmers from the original sample of 278. Step 1 included structural variables (irrigation management type, village location (DS), and seed duration) and accounted for 26.6% of the variance. Irrigation management was a significant predictor of yield. Farmers in communities with centrally managed resources produced greater yield per acre than those with locally managed resources (Figure 7, panel A). Farmers' location was also a significant predictor of yield. Farmers located in Kekirawa cultivated significantly less paddy yield per acre in comparison to the reference location Medirigiriya, with no difference between Thalawa and Medirigiriya. The duration of paddy seed planted was a significant predictor of yield, with longer seed duration associated with greater yields.

Table.7

Hierarchical Regression predicting rice yield per acre N=233)

Variable	ΔR^2	B	SE	β
Step 1	.27			
Centrally vs. Locally Managed		19.67	4.07	$.30^{***}$
Location				
Thalawa vs. Medirigiriya		-3.08	4.51	.05
Kekirawa vs. Medirigiriya		-31.80	4.67	$-.45^{***}$
Paddy Seed Duration		19.29	5.83	$.20^{***}$
Step 2	.03			
Centrally vs. Locally Managed		19.67	4.07	$.30^{***}$
Location				
Thalawa vs. Medirigiriya		-3.08	4.51	.05
Kekirawa vs. Medirigiriya		-31.80	4.67	$-.45^{***}$

Paddy Seed Duration		19.29	5.83	.20***
Efficacy (High vs. Low)		-6.49	4.02	-.09
Drought Risk Perception				
Very Low vs. High		10.28	5.55	.14^{+}
Low Vs. High		11.79	5.81	.15*
Medium Vs. High		11.23	5.34	.16*
Step 3	.01			
Centrally vs. Locally Managed		19.37	4.15	.30***
Location				
Thalawa vs. Medirigiriya		-5.40	5.04	-.80
Kekirawa vs. Medirigiriya		-33.01	4.73	.47***
Paddy Seed Duration		18.50	5.88	.19**
Efficacy (High vs. Low)		-18.28	8.74	-.26*
Drought Risk Perception				
Very Low vs. High		-1.98	9.66	.30
Low Vs. High		2.50	11.28	.03
Medium Vs. High		.88	9.77	.01
Risk Perception X Efficacy				
RP (VL vs. H) X EfficacyHL		17.32	11.31	.21
RP (L vs. H) X EfficacyHL		12.42	12.72	.15
RP (M vs. H) X EfficacyHL		14.69	11.65	.18
Step 4	.00			
Centrally vs. Locally Managed		19.51	4.15	.30***
Location				
Thalawa vs. Medirigiriya		-4.64	5.10	-.07
Kekirawa vs. Medirigiriya		32.55	4.76	-.47***
Paddy Seed Duration		18.04	5.90	.19**
Efficacy (High vs. Low)		18.26	9.67	.03*
Drought Risk Perception				
Very Low vs. High		2.40	9.67	-.03
Low Vs. High		2.12	11.29	.03
Medium Vs. High		2.04	9.84	.03
Risk Perception X Efficacy				
RP (VL vs. H) X EfficacyHL		17.67	11.31	.21
RP (L vs. H) X EfficacyHL		12.76	12.72	.15
RP (M vs. H) X EfficacyHL		14.00	11.67	.17
Adaptation (Yes vs. No)		-5.70	5.71	-.06

Note .*Total* R^2 *= .30* ***$p < .001$, ** $p <.01$, * $p <.05$, + $p <.10$

The second step tested H2 that the PMT-based model would predict significantly more variation in paddy yield/acre than a strictly structural model. Also, the model tested H3 that increases in efficacy and risk perception would contribute to increases in yield/acre. Step two added drought risk perception and farming general self-efficacy as predictors. Step 2 was marginally significant above the structural model alone (ΔF (4,223) = 2.03 p = .091) and explained an additional 2.6% of the variation in paddy yield. Farmers' level of risk perception was a significant predictor of yield/acre. In comparison to farmers high in risk perception, farmers with very low, low, or medium risk perception had a greater yield (Figure 7 panel B). There was no significant relationship between self-efficacy and yield/acre (Figure 7 panel D).

The third step tested the interaction between efficacy and drought risk perception. Step 3 was not a significant predictor above the previous models (ΔF (3,220) = .01, p = .471) and only explained an additional .8% of the variation in paddy yield. The interaction between level of efficacy and risk perception did not significantly predict farmers' rice yield.

The fourth step tested H4; that increases in adaptive behavior would produce greater yield/acre. Step 4 was not a significant predictor above the previous models (ΔF (1,219) = .99, p = .319) and explained an additional .3% of the variation in paddy yield. There was no significant relationship between whether a farmer performed an adaptation and paddy yield/acre (Figure 7 panel C).

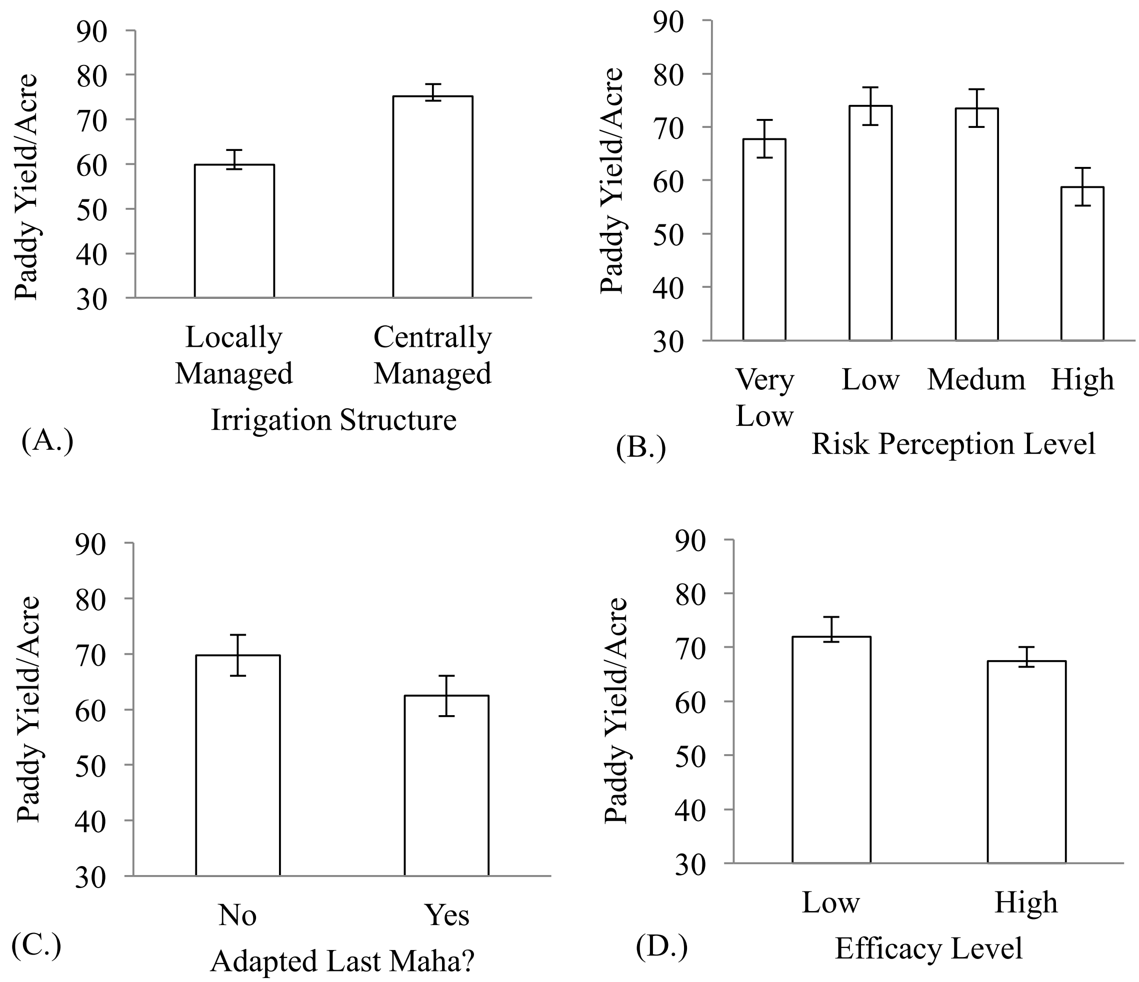


Figure 7. Mean Paddy Yield/Acre for farmers (A.) in locally managed and centrally managed villages (B.) based on risk perception level (C.) based on efficacy level (D.) based on whether they used an adaptation technique last Maha (bars represent standard error).

Discussion

In this study, we explored the role that structural factors (irrigation management, location, seed duration), psychological factors (efficacy, risk perception) and adaptation had on actual farming productivity (paddy yield/acre). For hypothesis 1, we anticipated that communities with locally managed resources would out produce communities with centrally managed resources. However, our results showed that farmers in communities with centrally managed irrigation systems had higher yields/acre than farmers in communities with locally managed irrigation. This contradicts previous research which suggests communities with locally managed resources have higher social capital and better access to information leading to greater productivity (Agrawal, 2003; Fiszbein, 1997a; Ostrom & Hess, 2007). One explanation for this finding could be that the Mahaweli Project was succeessful at mitigating the effects of drought on farmers' paddy production within communities with centrally managed irrigation. Communities who had centrally managed irrigation are "guaranteed" a certain amount of irrigation water, which may have buffered the detrimental effects of drought on their yields. We also looked at whether differences in participants' years as a farmer explained the differences in productivity between locally managed and centrally communities. However, our follow-up analysis suggested there was no difference between farming experience based on irrigation management type.

The second major hypothesis we investigated was the predictive capability of a PMT-based model on actual farm productivity. We found marginal support for the inclusion of the PMT-based model predicting rice yield/acre. This result was consistent with previous research demonstrating the importance of PMT constructs in predicting intention to adapt (Esham & Garforth, 2013; Grothmann & Patt, 2005; Truelove et al., 2015). However, we extended previous research by testing a PMT-based model across time scales, both before and after the growing season, which allows us to have more confidence in our results because we were able to measure success via measuring crop yield/acre. Previous PMT research measured intention and not actual performance of a behavior (Esham & Garforth, 2013; Grothmann & Patt, 2005; Truelove et al., 2015). Our result suggest that a PMT-based model can be predictive of actual success (paddy yield).

However, our findings regarding the psychological predictors embedded within the PMT-model were not what we anticipated. We expected farmers who had a higher perception of future drought risk would take protective measures, leading to greater paddy yield/acre. Our results were inconsistent with previous work and farmers who had the highest level of perceived drought risk produced the lowest amount of paddy yield/acre. One explanation for this surprising result is that farmers had a high fear appraisal about future drought risk and engaged in fatalism, which led them to fail to take protective measures (Grothmann & Patt, 2005). Alternately, farmers who perceived the likelihood of drought to be very likely may not have been willing to invest in a water-intensive crop such as paddy. Studies suggest that when drought is very likely some farmers switch to less water-intensive crops (Satyanaranyana, Thiyagarajan, & Uphoff, 2007; Tambo & Abdoulaye, 2012).

We also expected that farmers who were more efficacious about their farming ability would produce greater paddy yield. Our results were inconsistent with past research and we did not find support for our hypothesis. Our finding may be a result of farmers with very high self-efficacy feeling overconfident in their ability and not adjusting their agricultural practices accordingly. This conclusion is consistent with past research that showed a negative relationship between self-efficacy and performance when measured across time and not between individuals (Powers, 1991; Vancouver, Thompson, Tischner, & Putka, 2002). Previous feedback can elevate self-efficacy leading to overconfidence in a subsequent task (Vancouver et al., 2002).

Finally, we did not find a significant relationship between whether farmers used an adaptation technique and their paddy yield/acre. This result was inconsistent with previous research that links adaptation to increased yield (Pretty et al., 2006; Rockström et al., 2009).

However, in the future we can account for individuals who are unfamiliar with an adaptation technique, which can lead to a lag effect (Rusinamhodzi et al., 2011).

One interesting result that we explored, although we did not have a directional hypothesis, was the influence that village location had on paddy yield/acre. Villages located in Kekirawa had significantly lower paddy yield/acre than the other villages. Potentially, the villagers in Kekirawa lacked the same irrigation resources that the other communities received. Additionally, villages in Kekirawa received less rainfall than villages in the other DSs. This result suggests that the location of communities can serve as an important control variable when testing a PMT-based model.

Overall, the structural variables (irrigation structure, location, seed duration) were predictive of paddy yield and explained more than 25% of its variance. In comparison to other studies testing PMT in the climate change adaptation domain, the structural variables in our study explained a relatively large percentage of the outcome measure (Esham & Garforth, 2013; Grothmann & Patt, 2005) Meanwhile, the psychological variables (risk perception, efficacy) were not as important to our model. This could be due to limitations involving the psychological variables used in our survey including potential measurement error.

Limitations and Future Directions

There are several limitations to our study. First, the drought risk perception questions asked farmers for the likelihood of drought occurring within the next five years. We initially sought to gather information about longer-term weather trends as this is part of a long-term project where farmers will be reassessed in two years. However, this may not have been the best approach to test how farmers' drought risk perception affected paddy yield/acre just a few months later. In subsequent studies, we could frame the drought risk perception items based on the timetable of the follow-up survey. Hence, for the present study we could have asked whether farmers thought there would be an increase of drought in the upcoming season.

We should also strive to improve the construct validity of the drought risk perception items in follow-up studies. Risk perception as defined by PMT, is the likelihood and severity of a particular threat (Grothmann & Patt, 2005; Rippetoe & Rogers, 1987). In the present study, we were only interested in how the perceived likelihood of a threat influenced yield. Yet, farmers may have perceived that drought was likely but anticipated no adverse effects, leading them not to take protective measures. Therefore, in future research, we could expand the risk perception items to include the perceived severity of the threat.

Our farming efficacy items suffered from negatively skewed and unbalanced distributions where the vast majority of farmers considered themselves “highly efficacious”. Unbalanced data causes individual responses to convey very little meaning and makes it harder to find a desired effect during hypothesis testing (Clark & Watson, 1995). One explanation for the skewed responses is social desirability bias, where individuals adjust their responses to be perceived in a positive light (Fisher, 2000). Additionally, we were unable to create a farming self-efficacy scale due to the items having a low internal consistency. In follow-up studies, improving the construct validity of this scale is imperative. A potential solution for increasing the reliability is to extend the response options beyond three (Cicchetti & Tyrer, 1982; Preston & Colman, 2000). We used a three-item Likert scale on the efficacy items based on the recommendations of our collaborators within Sri Lanka and due to the fact that the survey was conducted face to face in an interview format. However, previous research has suggested in terms of general understanding of the meaning of behind the response options a five-point Likert scale is preferred (Preston & Colman, 2000). Support for a five-point Likert scale is the developing world has been shown in surveys investigating social support, depression, and quality of life (Rahman, Iqbal, & Harrington, 2003; The WHOQOL Group, 1998)

We made an effort to construct an adaptation scale that would be representative of the most commonly used agricultural adaptation practices within Sri Lanka. Therefore, we conducted interviews with local officials in the agricultural and irrigation department within Sri Lanka when drafting the adaptation measure. Additionally, we held focus groups with farmers to obtain a list of their most commonly used adaptation practices. However, after analyzing the data, it became apparent that there was a distinct possibility that we failed to capture the wide array of potential adaptations. In the future, we may need to increase the number of adaptation questions asked in the survey.

In future studies we can expand upon how we incorporate PMT constructs in our hypothesized model. First, we can investigate a potential feedback loop between how performance influences the efficacy of a farmer. According to Social Cognitive Theory, an individual's performance on a task can influence their level of self-efficacy (Bandura, 2001). For example, would a poor growing season lead farmers to have lowered perceived self-efficacy, which could influence their future adaptive behavior? Additionally, we can expand our model by incorporating perceived response (adaptation) cost from PMT. Potentially the cost to perform an adaptive behavior was greater than the perceived threat which may lead the farmers to fail to take action. Finally, in future studies we can test our hypothesized model using structural equation modeling.

Summary

Even with these limitations, this study is an important step toward furthering our understanding of the role that structural and psychological factors have on productivity. The current study provided a unique contribution to the literature as the first study to look at structural factors and use a PMT-based model to test actual productivity. We found that centrally managed communities outperformed locally managed communities. Additionally, while there was marginal support for the inclusion of psychological variables in our model, the structural variables were more important in explaining the variability of paddy yield/acre. Overall, this study adds an important contribution to the literature on CPR management and the influence of psychological factors on climate change adaptation.

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CONFERENCE PRESENTATIONS

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Poster Presentation at the Society of Southeastern Social Psychologists Athens, Georgia, October 2014
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