Households' Adoption of Drought Tolerant Plants: An Adaptation to Climate Change?

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Abstract

Declining water availability is a predicted consequence of climate change, and water conservation by households can be a useful adaptation strategy. Households in the Midwest face increased variation in water availability, in particular, more frequent droughts. Residents' perception of climate change and interaction with social and environmental systems can contribute to households' adoption of drought tolerant plant (DTPs) as an innovation to conserve water use. Using data from a household survey conducted in 2014, adoption of DTPs was analyzed with a univariate probit model. Variables were classified into five categories: 1) perceptions of climate change, 2) effects of attitudes and opinions, 3) yard management, 4) trust in information sources about soil and water, and 5) demographic characteristics. The results indicated that concerns about droughts, mowing lawns high, and more time spent gardening were significant determinants of DTPs adoption. More trust in soil and water information from water groups/projects was associated with higher adoption of the water conserving practice. In addition, respondents with either very low or very high household incomes, who own their home, and live in rural areas were significantly more likely to adopt.

Key words: Adaptation, adoption, climate change, drought tolerant plants, gardening, residential water conservation

JEL codes: C25, D12, Q25, Q54.

Introduction

In many regions, climate change will not only manifest itself as gradual changes in average conditions, but changes will likely occur in the frequency and intensity of extreme events (Angel and Huff 1997; Arnell 1999), such as extreme heat or cold for short periods, or intensive rainfall events or frequent droughts (Alauddin and Sarker 2014; Wanders and Wada 2015). Traditionally, the Midwest received enough rainfall for both crops and urban landscapes, but it is increasingly threatened by droughts along with most other regions of the country, for instance, a severe drought struck the Midwest in 2012. Projections on different scales have been derived from various models with relatively unanimous findings (e.g. Arnell 1999; Murray, Foster, and Prentice 2012; Sinha and Cherkauer 2010). Studies reported that hotter summers with longer dry periods and milder, wetter winters will be more likely to occur in the Midwest (EPA 2014). The potential impacts of these changes on water resources are likely to increase in magnitude, diversity and severity in future decades (IPCC 2014).

Adaptation to drought has fundamental significance for sustainable use of water resources and can inform policy design to improve households' adaptability to climate change. Effects from adaptation are increasingly observed not only in ecological systems, but from human adjustments to resource availability and risk management at different scales (Adger, Arnell, and Tompkins 2005; Smith et al. 2000). Constrained by available water resources, households can adopt different strategic options, one of which is to appropriately manage residential landscapes (Martin, Peterson, and Stabler 2003). It has been documented that residential yards take 50-90% of household water consumption and the majority of the water is used to irrigate turf grasses (Hurd, Hilaire, and White 2006; Sovocool, Morgan, and

Bennett 2006). Residential landscapes have been confirmed by studies to be complex adaptive systems (Cook, Hall, and Larson 2012), which is an important issue when looking at adaptation strategies at regional scale (Dupont and Renzetti 2013; Yabiku, Casagrande, and Farley-Metzger 2008). Thus, reasonable landscape management could ease the limitation of water availability and better prepare homeowners to cope with future climate risks.

Adoption of drought tolerant plants (DTPs) is expected to be a promising strategy to deal with regional water constraints induced by climate change, and assessment of households' adoption of DTPs is thus important. Homeowners are adopting DTPs to cope with water scarcity resulting from climate change, especially in some drought-stricken and urban areas of Florida (Shober, Denny, and Broschat 2010), as well as New Mexico (Hurd 2006), Nevada (Curtis and Cowee 2010) and other western states. Landscape choices by homeowners have been examined in the literature (e.g., Hurd 2006), focusing on the effects of water cost, number of children, education, responsibility for conserving water and location.

However, to the best of our knowledge, it remains unclear how residential adoption of DPTs is affected by households' perception of climate change, attitudes towards water quality, trust in information providers, and other socioeconomic factors. Climate change perceptions may be more important in areas that have not typically been drought-prone. Therefore, to help achieve effective water conservation and improve residents' adaptive capacity regarding water scarcity, we study households' adoption of DTPs in an urbanizing watershed in the Midwest. A deeper understanding of the important behavioral factors affecting households' adoption of DTPs can provide insightful implications for policy development and educational efforts related to residents' adaptation to climate change.

The overall framework presented in this paper is depicted in figure 1. Focusing on households' adaptation in response to perceptions of climate risks and water scarcity, and interactions with social and environmental systems, we investigate factors affecting residents' adoption of DTPs as a way of conserving water use. A review of the literature enables us to identify specific variables for inclusion in our conceptual model.

Literature review

Adaptation to climate change and households' water conservation practices

The warming of the planet's surface over the past 50 years has complex influences on environment, water resources, and society, and evidence shows "the regional changes have been far more profound than the global warming [as] noted by the IPCC" (Vaughan et al. 2003: p224). Impacts on water resources are important drivers to implement adaptation strategies dealing with climate change (IPCC 2014). As a consequence of predicted changes on climate and water resources, people will make adjustments or changes to their lifestyles. Water shortage puts residents at risk and influences their living status (Balling and Gober 2007; Cook, Hall, and Larson 2012), in particular for those living in cities of arid or semiarid regions. The local impacts of climate change usually leave households fewer alternative options and specific adaptations will substantially affect the benefits or losses associated with those impacts. At the residential level, homeowners' coping capacity is mainly restricted by personal awareness of climate change effects, undervaluation of potential losses, information availability on adaptive options and individual financial feasibility (Adger, Arnell, and Tompkins 2005; Adger et al. 2009; Kusangaya et al. 2014).

Residential yards provide fundamental community amenities and cultural values, for example, a sense of place for residents and neighborhood (Cook, Hall, and Larson 2012; Martin, Peterson, and Stabler 2003). However, irrigation of these yards takes a substantial amount of water to maintain various social and cultural values. For instance, in Las Vegas, the residential irrigation system uses approximately 60% of all the water (e.g., Devitt, Carstensen, and Morris 2008), so efficient water use for plants could potentially reduce household water consumption (Hurd 2006; Shober, Denny, and Broschat 2010). Water conservation techniques include “smart irrigation” controllers (McCready and Dukes 2011; Nautiyal et al. 2015) and residential micro-irrigation systems (e.g. sprinkler, dripping systems) (Haley, Dukes, and Miller 2007; Volo, Vivoni, and Ruddell 2015). However, the amount of irrigation water usually equates to two to three times the amount of water required by the plants (Haley, Dukes, and Miller 2007; Scheiber and Beeson 2006). Thus, an overirrigation problem exists for residential installations (McCready and Dukes 2011; Shober, Denny, and Broschat 2010).

Moreover, one of the effective ways to conserve water and prepare for uncertain water availability is to develop low-water-consuming landscapes (Sovocool, Morgan, and Bennett 2006). In the scholarship of water conservation by homeowners, water management practices mainly include irrigation planning and landscape maintenance (Scheiber and Beeson 2006; Volo, Vivoni, and Ruddell 2015), efficient water use for alternative landscape plant species and native landscape ornamentals (Hurd, Hilaire, and White 2006; Shober, Denny, and Broschat 2010), and xeriscape conversion (Chow and Brazel 2012; Sovocool, Authority, and Morgan 2005; Sovocool, Morgan, and Bennett 2006). Smith and Fellowes (2014) studied outcomes of different combinations of lawn grass species and mowing regimes in terms of ground cover and plant diversity. Volo, Vivoni, and Ruddell (2015) showed that the combined application of appropriate irrigation planning and various landscape management alternatives can help residential plants withstand moisture deficits under small and infrequent irrigation events in water-scarce municipal regions. Xeriscaping is viewed as a good way to reduce residential water use and has been used in some southwestern states (Sovocool, Morgan, and Bennett 2006). Some fundamental principles are identified with the application of xeriscaping, including rational planning, low irrigation, and planting low water-consuming plants (Hurd, Hilaire, and White 2006).

In most cases of residential landscapes, the planting of drought tolerant plant species is one of the essential components (Hurd 2006; Lockett et al. 2002). In horticulture, these species are also frequently mentioned as “drought resistant plants”, “desert plants”, “xeriscape plants”, etc. Though there is no unified definition for drought tolerant plants, most of them are found to be native plants, consuming less water and tolerating some dry conditions better than other plants. In studying public opinions on water conserving practices in western Texas, Lockett et al. (2002) found a high acceptance of DTPs by the public, especially those plant species that could conserve water and be attractive. Focusing on a public opinion survey of homeowners, Hilaire, VanLeeuwen, and Torres (2010) studied the valued landscape features of urban landscapes and factors affecting households’ willingness to reduce water use in urban landscapes. Generally speaking, DTPs require less water once established, exhibit high water use efficiency, make yard maintenance easier in the long term, and present as much comfort and aesthetic value as other plants and turf grass (Hilaire, VanLeeuwen, and Torres 2010; Howley 2011; Shober, Denny, and Broschat 2010).

Behavioral factors impacting adoption of DTPs as an innovation

Adoption of innovations relating to environmental practices (Pannell et al. 2006; Prokopy et al. 2008) and water conservation (Alam 2015; Alauddin and Sarker 2014) has been well studied in the agricultural sector. Potential elements affecting adoption of innovations have been identified, including cost of adoption, operator's age, education, geographic area, and time spent (Arbuckle, Morton, and Hobbs 2013; Kemp and Volpi 2008; Pannell et al. 2006; Patt and Schröter 2008; Prokopy et al. 2008; Rogers 2003; Smith et al. 2014; Weber and McCann 2014). Moreover, higher farm household income can increase their ability to bear risks and contribute to the increase of adoption probability in many cases (Khanna, Epouhe, and Hornbaker 1999; Roberts et al. 2004). Information has been considered to facilitate capacity building and policy development regarding agricultural adaptation to climate change (Alam 2015; Arbuckle, Morton, and Hobbs 2015). Perceptions of extreme weather events and their impacts varied among farmers and these perceptions affected farmers' adaptation strategies based on an Iowa farmer survey (Arbuckle, Morton, and Hobbs 2013, 2015).

For homeowners, many studies have documented the adoption of environmental and water conserving practices, focusing on residential landscape choices and factors influencing those choices including behavioral, demographic and environmental aspects (e.g., Howley 2011). A study by Sovocool, Morgan, and Bennett (2006) on residential landscapes in Arizona found that landscape aesthetics and ease of maintenance are two critical considerations for homeowners when choosing landscape types. Hurd (2006) examined landscape choices of homeowners in three cities of New Mexico and identified various factors affecting water conservation, including water cost, children, education, responsibility for conserving water and location on landscape choices. Hilaire, VanLeeuwen, and Torres (2010) and Smith and Fellowes (2014) have shown that water shortages, environmental concerns, information on water, among other factors, could effectively engender adoption of DTPs and reduction of water use on yards. Their findings also indicated that residents living in dry areas were satisfied with DTPs which provided desirable landscapes.

Other research examined adoption of DTPs as affected by respondents' attitudes to landscapes, perceptions of climate conditions and landscapes' water needs. Yabiku, Casagrande, and Farley-Metzger (2008) studied the effects of individual's attitudes on landscape preferences and investigated the relationship between changes of the attitudes and more environmentally friendly behaviors. Through analyzing the effects of attitudes on the choices among xeric, desert, and mesic landscapes, their results showed that preferences differed with varying environmental attitudes, as well as the aesthetic effects and demographics of individuals. By analyzing the effects of changes in temperature, precipitation, and drought conditions on residential water use, Balling and Gober (2007) pointed out the importance of residents' perception of landscape's water needs. Their findings confirmed that social and behavioral factors were among the fundamental explanations of water conservation, in particular, residents' willingness and ability to respond to their perceptions through changing landscaping practices.

In addition, experts have analyzed the effects of information providers, education programs and income levels on the adoption of DTPs. Lockett et al. (2002) indicated correct information from workshops on principles of low water landscapes could increase public acceptance of DTPs. Hilaire, VanLeeuwen, and Torres (2010) found that the fear of water shortage could significantly reduce landscape water use by communities in desert regions of New Mexico, and they pointed out that public education programs on water conservation could influence residents' landscape choices. Helfand et al. (2006) reported that high income can facilitate households' ability to pay for the establishment and maintenance of DTPs.

Therefore, based on the review of literature, we find that adoption of DTPs as a kind of innovation could be affected indirectly by a variety of variables including climate conditions, water needs, information providers, education, and demographics. In studying adoption by households, most research studies were restricted to effects of similar combinations of variables. However, one key limitation of current analysis on DTPs adoption and water conservation by residents is that most studies ignore the influence of people's perceptions about climate change, attitudes towards the local environment and trust in information providers influencing yard management choices and water consumption behaviors. Though most of the studies were focused on residential adoption of water conservation practices in the south and west of US, no research has been carried out on adoption of DTPs as a way of adapting to climate change in the Midwest.

Conceptual framework

Independent variables used in the model and their hypothesized signs are given in table 1. In our model, explanatory variables fall into five major categories: 1) perceptions of climate change, 2) neighbors' opinions and residents' attitudes, 3) yard management practices, 4) trust in information sources about soil and water, and 5) demographic characteristics. We hypothesize that households' adoption of DTPs is a function of variables in the above categories. These hypotheses are built upon findings from existing studies. As indicated in the literature review, landscape choices made by homeowners can be affected by specific climate characteristics (Martin, Peterson, and Stabler 2003). Perceptions of climate change reflect respondents' personal experience and concerns regarding droughts and intense rains as climate change indices. Therefore we hypothesize homeowners' adoption of DTPs to be correlated with their perceptions of climate change. Specifically, if residents are more concerned about longer droughts, they are expected to plant more DTPs. Adoption of DTPs could reduce high water bills due to residential lawn irrigation and also benefit the environment as less irrigation is needed and less irrigation runoff would reduce sediments and pollution in the watershed. On the contrary, if they are more concerned about more frequent intense rains, lower adoption of DTPs would be expected.

Valuing neighbors' opinions and residents' environmental knowledge have different effects on adoption. The effects of neighbors' opinions about lawn care choices relates to whether households get private satisfaction or gain status if neighbors appreciate the lawns' appearance (Kiesling and Manning 2010). Homeowners who want to obtain private satisfaction and self-identity through neighbors' compliments on their nice lawn would tend to irrigate lawns more frequently (Larsen and Harlan 2006). Thus we hypothesize that these individuals would be less likely to adopt DTPs. Residents' knowledge about management practices investigates whether they think the way they care for their yards would influence local water quality (Clayton 2007). Homeowners who agree that their yard care influences local water quality tend to make changes and protect local waterways for the benefit of their community and environment (Kiesling and Manning 2010). Therefore we hypothesize those residents would choose to plant more DTPs.

Variables regarding yard care include adopting mowing lawns high, never watering or only watering their lawns when in a severe drought, and time spent in yardwork. The practice of mowing high, referring to setting mowers at the highest setting (4 inches), can promote the root system of turf grasses to absorb deeper soil water and households can thus use less irrigation water (Smith and Fellowes 2014). Thus, we hypothesize homeowners to be more likely to adopt DTPs if they mow their lawns high. For yards' watering status, the literature shows that households' water conservation practices can determine their choices of plants in their yards (Martin, Peterson, and Stabler 2003; Scheiber and Beeson 2006). Therefore, we hypothesize homeowners would be more likely to adopt DTPs if they seldom or never water their lawns. The amount of time spent taking care of the yard reflects homeowners' preference for gardening (Lockett et al. 2002; Martin, Peterson, and Stabler 2003). We hypothesize that residents would be more likely to adopt DTPs if they spend more time on yard or lawn management activities.

Access to information and trust in information providers can be barriers/stimuli and limit/promote decision making about innovation adoption (Lockett et al. 2002). Homeowners trusting in specific information providers would believe and follow what they suggest regarding yard water management, lawn maintenance, landscape choices, and so on. Different providers spread varying information based on their objectives and thus their information may have diverse effects. For example, information from local water groups and projects probably encourages less water-consuming and more environment-friendly yard management and maintenance practices, e.g., mowing lawn high, watering lawn less frequently, applying less fertilizer, planting some native plants, etc. Information from local news media could inform residents of federal and state regulations and raise people's awareness of potential problems. Thus we hypothesize that homeowners who trust in local water groups and local news media are more likely to adopt DTPs. On the contrary, information from lawn care companies who mow, prune, and apply fertilizers and pesticides would not encourage the planting of DTPs and most of their advertisements promote new tools/machines, fertilizers, etc. From this perspective, we hypothesize that homeowners who trust in lawn care companies are less likely to adopt DTPs.

Among demographic factors, education and income variables assume a link between knowledge, ability and willingness to adapt to climate change and the current application of adaptation strategies (Alam 2015; Alauddin and Sarker 2014; Cook, Hall, and Larson 2012; Hilaire, VanLeeuwen, and Torres 2010; Lockett et al. 2002). Homeowners with higher levels of these attributes are not only exposed to more ideas and have more experience making decisions and effectively using information (Loss, Ruiz, and Brawn 2009; Prokopy et al. 2008), but are motivated to learn about consequences of climate risks and to take appropriate measures to mitigate negative outcomes (Adger, Arnell, and Tompkins 2005; Volo, Vivoni, and Ruddell 2015). Thus, we hypothesize respondents with either better schooling or higher income to be more likely to adopt DTPs. Property ownership determines whether the residents can make long-term gardening plans or not. People who own their home can receive a stream of future benefits from planting DTPs, so we hypothesize residents owning their home are more likely to adopt DTPs compared with those who rent. Variables on gender and children are used as control variables in the regression. Residential choices regarding yard practices can differ due to different behaviors and preferences by men and women, and can be affected by different outdoor activities if they have children (Cook, Hall, and Larson 2012). However, depending on the context, findings differ on whether male or female headed households are more likely to adopt DTPs (Bryan et al. 2009). Households having children may be less likely to water their lawn and garden (Dupont and Renzetti 2013), but they can also play on the lawn. Lastly, location variables are good predictors of water consumption and areas of land (Cook, Hall, and Larson 2012; Sovocool, Authority, and Morgan 2005). Households living far away from urban areas would have larger areas to irrigate and, contrary to urban homes, they may actually need to install expensive irrigation systems to water plants that are far from the house. So we hypothesize them to be more likely to adopt DTPs to reduce water bills and/or the likelihood of plants dying.

Data and Methods

Data

We use data from a survey of Columbia, Missouri households in single-family residences with yards. The survey was conducted from February to May of 2014. The survey covered specific practices adopted by the residents regarding water use, conservation and pollution related to their lawn and garden management as well as their attitudes towards these water issues. Some of the questions were designed to learn whether households had adopted drought tolerant plants as a residential water conservation practice and how the household's and yard's characteristics had affected the adoption decision. In designing the questionnaire, the Dillman survey method (Dillman 2000) was followed. A focus group pretesting method was utilized and minor modifications were made based on comments of participants. Of the

2000 questionnaires mailed out in the spring of 2014, there were 751 homeowners providing responses on the DTPs adoption question and the effective response rate was 44%. A total of 126 observations were excluded due to one or more missing values, in particular, on income, education, information sources, etc. Among the remaining 625 observations, 200 households had adopted drought tolerant plants in their gardens so the adoption rate was 32%.

The variables shown in table 1 reflect combining of some response categories in the original survey. The dependent variable was adoption of drought tolerant plants (1=currently use it, and 0=otherwise, including responses of know how to use it, but not using it, somewhat familiar with it, but not using it, never heard of it, and not applicable). The explanatory variable of adoption of mowing lawn high was treated in the same way as adoption of DPTs. Variables regarding perceptions of climate change, effects of neighbors' opinions on lawn care choices and water quality were obtained by asking respondents to rate their practices on various attributes using a Likert scale (1 = strongly disagree, 5 = strongly agree). Responses of 4 and 5 were combined into an agree category and responses of 1, 2 or 3 were combined into the base category in the regression. Time variables were recoded to reflect three subcategories, i.e., 0−5 hours, 6−15 hours (base category) and greater than15 hours. Education included three subcategories, specifically, some schooling or high school diploma, some college or 2 year college degree (base category), and 4 year college or post-graduate degree. Annual household income was divided into five subcategories- less than $24,999, $25,000−$49,000 (base category), $50,000−$74,999, $75,000−$99,999 and more than $100,000. Location variables included living in city, suburban areas, and rural areas (base category). Four categories of frequency of watering lawns were provided to respondents: watering yard on an as-needed basis, only in summer, only with severe drought and never watering. We combined the last two as the low watering variable and the rest as the base in the regression. Response options for the degree of trust in various information providers included not at all, slightly, moderately, very much and not familiar. For for each information provider, the moderate and very much categories were combined and the others were combined into a base category. Dummy variables were also used for variables of male (vs. female), owning home (vs. rent) and having children under the age of 12 (vs. none).

Probit adoption model

A probit or logit model is commonly used in studies of adoption and the factors influencing adoption likelihood (Hahn and Soyer 2005). Focusing on the adoption of DTPs, a household either adopts $(\mathrm{y}=1)$ or does not adopt $(\mathrm{y}=0)$, constituting the dependent variable. Then, given various factors influencing the probability of adoption for a resident $\mathrm{x}=x_1, x_2, x_3, \ldots, x_k$, the adoption probability is expressed as $p_i=\mathrm{P}(Y_i=1|x_i)$ (Greene 2005). In our adoption model, all the variables were binary, where 1 represents agree or yes, and 0 represents no or otherwise. Probit models have been preferred primarily due to the relative ease of computation. For probit models, we assume p_i is given by the standard normal distribution function $\Phi(x'\beta)$. Thus given the dichotomous nature of the dependent variable, the following univariate probit model is used:

$$\mathrm{P}(\mathrm{y}=1|x_1, x_2, \ldots, x_k)=\Phi(\boldsymbol{x}'\boldsymbol{\beta}) \qquad (1)$$

where $\boldsymbol{x}=x_1, x_2, \ldots, x_k$ are explanatory and control variables, and $\boldsymbol{\beta}=\beta_1, \beta_2, \ldots, \beta_k$ are coefficients for each corresponding x variable.

All the analysis are conducted using the data analysis package STATA version 13.1. For probit models, the coefficients cannot be directly explained as marginal effects, and marginal effects for discrete (i.e., binary or dummy) variables used in our model have to be computed separately.

For a categorical variable x_k,

$$\text{Marginal Effect of } x_k = Pr(y = 1|x, x_k = 1) - Pr(y = 1|x, x_k = 0) \quad (2)$$

Results

Summary statistics for the 625 observation dataset can be found in table 2. Approximately 32% of the respondents reported adopting drought tolerant plants in their yards. More people were concerned with long dry periods or drought (77%) than frequent intense rains (36%) which may relate to the drought the previous year. About 37% of the homeowners valued their neighbors' attitude towards the appearance of their lawns. Most people (87%) agree that the way they care for their yards could influence water quality in local streams and rivers. Regarding residential yard management practices, 66% of people set their mowers at the highest level. About 62% of the respondents never watered or only watered their lawns when in a severe drought. More than half of the households (56%) spent $6-15$ hours per week on lawn maintenance, and the residents spending $1-5$ hours and more than 15 hours per week were 20% and 23%, respectively.

Generally, more than half of the residents trusted information regarding soil and water from local watershed groups and projects (61%). Fewer people trusted lawn care companies and local news media (37% and 35%, respectively). The most common educational category according to the survey was completion of 4 year college or post-graduate degree (71%). Residents with education levels of some formal school or high school diploma or GED and some college or 2 year college degree were 10% and 20%, respectively. Respondents with income levels of \$50,000−\$74,999 and more than \$100,000 were 27% and 29%, respectively, and 7% had incomes less than \$24,999. According to the US census data for Columbia, Missouri, for the years 2009−2013, 54.5% of the residents aged 25 or higher had a bachelor or higher degree, and the median household income was \$43,262. The education and income levels of respondents may be fairly representative of the surveyed population of people living in single-family homes because our study area is a college town and those living in houses versus apartments would tend to have higher incomes.

For demographic characteristics, most of the respondents are male (62%) and almost all of them owned their home or had a mortgage (91%) rather than renting. Most of the people were living in the city (61%), with fewer living in suburban areas (25%) or in rural areas (13%).

Regression results and discussion

Because the five variable categories included a wide variety of independent variables used for the regression, we examined correlation coefficients for each pair of variables and tested for multicollinearity in the regression as a whole. For all pairs, the correlation coefficients had absolute values of smaller than 0.4. We found no evidence of multicollinearity, as indicated by values of variance inflation factor (VIF)[1]. The VIF values for all variables in the model were smaller than 2.4, with an average of 1.4, whereas a VIF of

[1] For the original model, we also included dummy variables on respondents' age, age of house, and money spent on yard care. However, there was strong correlation between age and income, as well as age of house and own home variable. Regarding money spent variable, one third of the observations had missing values. Exclusion of these variables improved the overall goodness of fit of the model.

greater than 8 indicates that a variable may be deemed a linear combination of other independent variables in the model. For models with binary dependent variables, the traditional ordinary least squares measure of fit, R^2, cannot be applied. Moreover, the regression had binary independent variables, so the appropriate measure reported in the probit regression results was a pseudo-R^2 value, which is a likelihood-based measure calculated by STATA. The measure ranges from 0 to 1 in general, with higher values indicating better fit for the model. The pseudo-R^2 value for the probit regression was 0.15 (table 3). The pseudo-R^2 value was low but acceptable in adoption studies (Alcon et al. 2014; Sharp, Daley, and Lynch 2011). This indicated that other variables not included in this regression probably affected the adoption of drought tolerant plants. The LR Chi-square indicated the model as a whole was significant, with a p value less than 0.01.

Probit regression results are shown in table 3. For this model, the values for marginal effects measured the conditional probability changes in adoption, given the level of the other independent variables. According to the results, concern about droughts was positively associated with adoption ($p<0.1$), while concern about intense rains was negatively associated with the adoption ($p<0.1$). These results are in line with our hypothesis that respondents who were concerned about longer droughts were more likely to adopt DTPs, and those concerned with more frequent intense rains were less likely to adopt (Hilaire, VanLeeuwen, and Torres 2010; Martin, Peterson, and Stabler 2003).

Regression results indicated households who agreed that the way they cared for yards could influence local water quality were significantly more likely to adopt DTPs ($p<0.05$), which was consistent with the literature. To be environmentally-friendly and benefit their community, residents are more willing to use plant species and reduce water pollution induced by yard fertilization and irrigation (Kiesling and Manning 2010). Regarding valuing neighbors' opinions on lawn care choices, the effect was not significant. This point indicates the self-identity and private status is probably not a barrier to the adoption of DTPs.

For yard management, the practice of mowing lawns high showed a positive and significant effect on adoption (p<0.01). This result fits with our expectation that setting the mowers at 4 inches could be positively correlated with the adoption of less water consuming vegetation. Using time spent category 6−15 hours as the base in the regression, the effect of category 1−5 hours was negative and significantly correlated with adoption (p<0.05) and the category >15 hours was positive and significantly correlated with the adoption (p<0.01). The results are consistent with our hypothesis. The respondents who spend more than 15 hours probably like to garden and are curious about plants. The lowest category would correspond to the time required to just mow the lawn. Very interestingly, the low watering variable reflecting never watering or only watering lawn in a severe drought was not significant *ceteris paribus*.

The trust in various information sources had mixed effects on adoption. Trust in information from local watershed groups/projects has a positive and significant effect on adoption (p<0.01) and it could lead to being13% more likely to adopt compared to the case of no trust. On the contrary, trust in information from lawn care companies has a negative and significant effect on adoption (p<0.05) compared to that of no trust. These findings are in line with our expectation as discussed before that effects of trust in information sources depend on aims and specific information these entities convey.

Regarding demographic characteristics, diverse effects were found in the model. Unexpectedly, education levels were nonsignificant. Very high annual household income (>$100,000) had significant effects on adoption (p<0.1) and residents with income in this category were more likely to plant DTPs in their yards, which is consistent with the research by Helfand et al. (2006) and Loss, Ruiz, and Brawn (2009) that wealthier people were more willing to pay for residential plant species. Meanwhile, respondents with very low incomes (<$24,999) were also significantly more likely to adopt (p<0.01), which is contrary to our expectation. However, this finding could be due to low income limiting household expenditure on the yard care and adoption of DTPs (Balling and Gober 2007; Cook, Hall, and Larson 2012). Contrary to Western states where residents replaced lawns with DPTs, in the Midwest adoption of DPTs would typically mean choosing to plant drought tolerant versions of trees and bushes in yards, rather than water consuming versions, which would reduce costs relative to lawn replacement. DTPs generally require less investment compared to planting water-consuming plants and lawns, in terms of expenditure on irrigation water, irrigation systems, fertilizer, maintenance equipment and professional services (Martin, Peterson, and Stabler 2003; Shober, Denny, and Broschat 2010). Regarding other demographic variables, being male was negative and significantly correlated with the adoption of DTPs (p<0.01). A male headed household would be 20% less likely to use DTPs. Literature has shown that gender may have mixed effects depending on the context (Bryan et al. 2009; Cook, Hall, and Larson 2012). Our result was in line with that of Larson et al. (2009), Martin, Peterson, and Stabler (2003) and Yabiku, Casagrande, and Farley-Metzger (2008). Men might express lower environmental concerns than women (Hunter, Hatch, and Johnson 2004). Residents owning their home were significantly more likely to adopt DTPs compared to those who rented. These were consistent with our predictions as people who are owning the property could probably make longer term plans for their yards, invest more time and money in yard management and maintenance, and care more about lawn related environment and related issues than those who are renting. The effect of a family with children was not significant. Residents living in city or suburban areas, versus those living in rural areas, were significantly less likely to adopt DTPs. Rural residential lots are larger and households might choose to plant DPTs due to the difficulty of watering large areas and saving time and money on yard care and maintenance.

Conclusion

One dimension of climate change is that rainfall would become more unevenly distributed in time, which could affect local availability and use of water resources (Wanders and Wada 2015). At the residential level, homeowners' adaptation to climate risks can be enhanced through adopting various practices to conserve water use. The adoption of drought tolerant plants for the landscape is considered to be a fundamental adaptation strategy.

There are multiple factors impacting households' adoption of DTPs and mixed effects were found in empirical studies (e.g., Bryan et al. 2009). By analyzing survey data from an urbanizing watershed in the Midwest, we found five fundamental points that could contribute to future policy design on adaptation to climate change and water shortages.

(1) Residents' concern about droughts and awareness of their actions on local water quality had positive effects on the adoption of DTPs, while concern with frequent intense rains had a negative effect on adoption.

(2) Residents' yard management practices regarding mowing lawns high and spending more than 15 hours on gardening had positive effects on adoption, while spending less than 5 hours had a negative association.

(3) Homeowners' trust in information from local watershed groups/projects was positively correlated with adoption, while if respondents trusted the information from local lawn care companies, they were less likely to adopt DTPs.

(4) Households with incomes less than $24,999 and greater than $100,000 were more likely to adopt and respondents owning versus renting their home were more likely to adopt.

(5) People living in city or suburban areas were less likely to adopt versus those living in rural areas.

Insights from the effects of perceptions regarding droughts and intense rains could motivate residential adaptation to climate change (Hurd 2006). Midwestern states are traditionally not drought-stricken, and local infrastructure and landscape design give little consideration to possible climate risks. That is part of the reason why the 2012 drought in the Midwest not only devastated agricultural production, but also brought damage to residential properties (USDA 2012). Given these facts, individuals' perceptions of climate risks could help prepare themselves for potential climate fluctuations with proactive strategies such as the adoption of drought tolerant plants.

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Table 1. Explanatory variables and definitions

Variables	Exp. sign	Definitions
Perceptions of climate change		
Drought	+	concerned about longer dry periods or drought (agree or strongly agree=1; otherwise=0)
Rain	−	concerned about more frequent intense rain (agree or strongly agree=1; otherwise=0)
Neighbors' opinions and residents' attitudes		
Nice lawn	−	important to me that my neighbors think I have a nice lawn (agree or strongly agree=1; otherwise=0)
Water quality	+	agree that yard care can influence water quality in local streams and lakes (agree or strongly agree=1; otherwise=0)
Yard management		
Mow high	+	set mower at highest setting (currently use=1; otherwise=0)
Low watering	+	never water or only water lawn when in severe drought (yes=1; otherwise =0)
Time		hours per month spent on yardwork during the growing season
0−5 hours	−	
6−15 hours	base	
>15 hours	+	
Trust in information sources		
Water group	+	local watershed group/project (moderately or very much=1; otherwise=0)
Media	+	local news media (moderately or very much=1; otherwise=0)
Lawn care company	−	lawn care company (moderately or very much=1; otherwise=0)
Demographic characteristics		
Education		highest grade in school completed by respondents
≤ high school	−	
2 year college	base	
≥ 4 year college	+	
Household income		total household income in 2013
<$24,999	−	
$25,000−$49,000	base	
$50,000−$74,999	+	
$75,000−$99,999	+	
>$100,000	+	
Home	+	own the home or have mortgage (yes=1; otherwise=0)
Male	+/−	family head is male (yes=1; female=0)
Children	+/−	have children under the age of 12 (yes=1; no=0)
Location		where the respondent is living
City	+	city of Columbia (yes=1; no=0)
Suburban	+	suburban area in or near the city (yes=1; no=0)
Rural	base	rural subdivision, isolated, non-farm or farm area (yes=1; no=0)

Table 2. Summary statistics (N = 625)

Variables	Mean	Std. Dev.	Min.-Max.
Dependent variable			
Adoption of DTP (drought tolerant plants)	0.32	0.47	0−1
Independent variables			
Perceptions of climate change			
Drought	0.77	0.42	0−1
Rain	0.36	0.48	0−1
Neighbors' opinions and residents' attitudes			
Nice lawn	0.37	0.48	0−1
Water quality	0.87	0.34	0−1
Yard management			
Mow high	0.66	0.47	0−1
Low watering	0.62	0.49	0−1
Time			
0−5 hours	0.20	0.40	0−1
6−15 hour	0.56	0.50	0−1
>15 hours	0.23	0.42	0−1
Trust in information sources about soil and water			
Water group	0.61	0.49	0−1
Media	0.35	0.48	0−1
Lawn care company	0.37	0.48	0−1
Demographic characteristics			
Education			
≤ high school	0.10	0.29	0−1
2 year college	0.20	0.40	0−1
≥ 4 year college	0.71	0.46	0−1
Household income			
<$24,999	0.07	0.26	0−1
$25,000−$49,000	0.19	0.39	0−1
$50,000−$74,999	0.27	0.44	0−1
$75,000−$99,999	0.18	0.38	0−1
>$100,000	0.29	0.46	0−1
Home	0.91	0.29	0−1
Male	0.62	0.48	0−1
Children	0.13	0.33	0−1
Location			
City	0.61	0.49	0−1
Suburban	0.25	0.43	0−1
Rural	0.13	0.34	0−1

Table 3. Results for probit regression

Independent variables	Coefficient	dy/dx
Perceptions of climate change		
Drought	0.24*	0.07
Rain	−0.23*	−0.07
Neighbors' opinions and residents' attitudes		
Nice lawn	−0.14	−0.04
Water quality	0.42**	0.13
Yard management		
Mow high	0.63***	0.19
Low watering	0.10	0.03
Time (base = 6−15 hours)		
0−5 hours	−0.41**	−0.12
>15 hours	0.41***	0.12
Trust in information sources		
Water group	0.41***	0.13
Media	−0.08	−0.02
Lawn care company	−0.27**	−0.08
Demographic characteristics		
Education (base = 2 year college)		
≤ high school	−0.29	−0.09
≥ 4 year college	−0.11	−0.03
Household income (base = $25,000−$49,000)		
<$24,999	0.64***	0.19
$50,000−$74,999	0.07	0.02
$75,000−$99,999	0.24	0.07
>$100,000	0.30*	0.09
Home	0.39*	0.12
Male	−0.37***	−0.11
Children	−0.16	−0.05
Location (base = Rural)		
City	−0.31*	−0.09
Suburban	−0.36*	−0.11
Constant	−1.27***	
Goodness of fit		
N	625	
LR Chi-square	115 (p < 0.01)	
Pseudo-R^2	0.15	
Variance inflation factor (VIF)	mean: 1.40 (min-max: 1.04−2.40)	

*p<0.10, **p<0.05, ***p<0.01

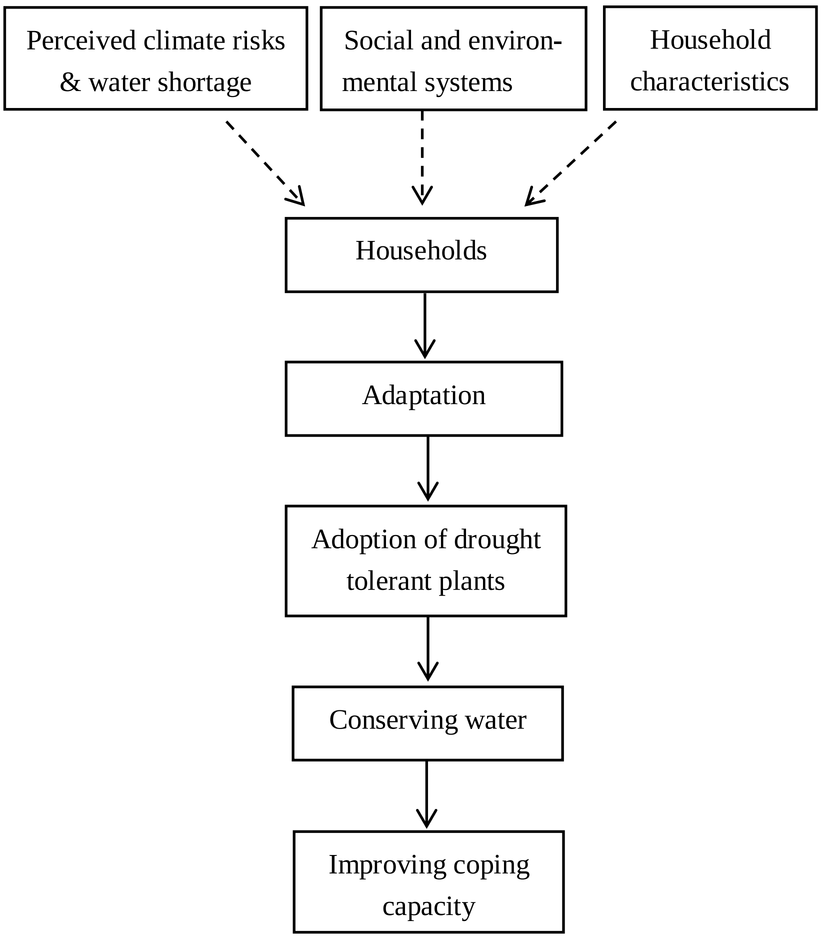

Figure 1. Flow chart of households' adaptation to climate change by adoption of drought tolerant plants

Notes: The dotted lines show perceptions of risks and water shortage by households and interactions between systems and households. The solid lines show causal relationships and decision processes.

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