# Drought intensity, future expectations, and climate-change adaptation

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**Abstract**: Using a survey of New Zealand farmers, we explore the effect of drought intensity on future climate expectations and plans for land-use change, focusing on the window of experience farmers use in planning. Results suggest farmers reference the recent past rather than the historical record, indicating farmers routinely update environmental signals. Higher expectations of drought are also positively associated with land-conversion plans. Our findings suggest that while weather shocks may speed adaptation in expectation of climate change, the relatively short period of reference over which farmers compare drought may concurrently decelerate adaptation as drought becomes the "new normal".

Climate change is projected to significantly alter the distribution of precipitation across New Zealand, exacerbating drought conditions. In general, New Zealand's drier regions will become drier in spring, its wetter regions will become wetter in winter, and most of the country will experience drought conditions at least 10% more often (Clark, Mullan, and Porteous 2011; Ministry for the Environment 2016). These regional and seasonal changes could have a large impact on New Zealand's agricultural sector and global dairy exports (Clark et al 2012; Reisinger et al. 2014), which represent a significant share of the country's economic output.

It is therefore important to understand the impact of climate change on farmer decision making. We explore the effect of recent drought intensity and past drought occurrence (which are both directly affected by climate change and highly relevant to farmers) on New Zealand farmers' perceptions of the risk of future climate change. Understanding these expectations has implications for climate-change adaptation policy as past research indicates that the likelihood of changing behaviour may be endogenous to the perception of risk (Mase, Gramig, and Prokopy 2017).

Demographics have been shown to strongly influence belief (or disbelief) in climate change. For example, well-educated young women are disproportionately likely to believe in climate change (e.g. Hornsey et al. 2016). However, values and ideologies have also been shown to be important factors: in the US, for example, political orientation influences belief in climate change and correlates with other determinants of climate change belief such as trust in scientific consensus, concern for the environment, hierarchical cultural values, and free-market ideology (Hamilton and Stampone 2013; Hornsey et al. 2016).

People may also reference past environmental, weather, and climate signals when thinking about climate change and forming expectations of future climate risk (Leiserowitz 2006;

Howe et al. 2012). Perceptions of the risk of climate change have been shown to increase after exposure to climatic signals such as flooding (Spence et al. 2011), changing precipitation patterns (Thomas et al. 2007), cyclones (Peacock, Brody, and Highfield 2005; Brown et al. 2018), and drought (Safi, Smith, and Liu 2012).[1] There is also evidence that normal variability in weather affects expectations regarding climate change. For example, the average July temperature in Europe has been shown to influence individuals' expectations of and concerns about global climate change (Lorenzoni and Pidgeon 2006)[2], as well as the local weather on the day of a survey on anthropogenic climate change (Li, Johnson, and Zaval 2011; Hamilton and Stampone 2013). However, most of these studies treat exposure to natural disasters and weather variability as dichotomous variables, ignoring measures of intensity in either an absolute or a relative sense.

We use a recent survey of New Zealand farmers to analyse future expectations regarding climate. Our study expands the literature on climate perceptions in three important respects. First, we consider the intensity of recent drought in two different ways to explain expectations of future drought. Second, we use historical drought data to explore the temporal dimensions of past experience on climate-change expectations. Third, because past research indicates that experiencing climate impacts can lead to adaptive behaviours such as changing land uses (Thomas et al. 2007; Kenny 2011; Higginbotham, Connor, and Baker 2013) and because the likelihood of changing behaviour may be endogenous to belief in climate change (Barnes and Toma 2012; Arbuckle et al 2013; Wheeler, Zuo, and Bjornlund 2013) and the perceptions of climate-change risk (Mase, Gramig, and Prokopy 2017), we link historical drought data with survey questions about previous and future land-use planning to understand likely pathways for adaptation, which may have significant impacts on agricultural profits and livelihoods.

We find that recent experience with drought has a significant effect on climate change beliefs. Moreover, farmers most strongly reference the past 5–10 years when evaluating drought intensity, indicating that they routinely update environmental signals. Furthermore, younger farmers, older farmers, and those with socially conservative outlooks are less likely to change their minds about future climate change, whereas middle-aged farmers and those with socially liberal outlooks are more likely to be influenced by recent drought. Finally, higher expectations of drought are positively associated with plans for land-use conversions in the near term. These results are robust to different definitions of drought as well as different times of year at which drought is measured. Our findings suggest that while extreme weather shocks may speed adaptation in expectation of future climate change, the relatively short period of reference over which individuals compare drought events may concurrently decelerate adaptation.

## Methods

We use logistic regression to analyse the determinants of future drought expectations. We include the potential evapotranspiration deficit (PED) as a measure of recent drought to understand its effect on expectations of future drought. Additionally, since the effects of climate change may significantly affect future conditions we also explore the interplay between experience, expectations, and planned land-use change.

*Empirical approach*

Survey respondents were asked "Which of the following best describes how you personally expect the prevalence of drought to change by 2050?"[3] They selected from six potential answers: "decrease a lot", "decrease slightly", "no change", "increase slightly", "increase a lot", or "don't know". We start by analysing whether respondents believe that drought will increase, sorting people into two categories as per Brulle, Carmichael, and Jenkins (2012). Responses that indicate that drought will increase are coded 1, while the remaining responses are coded 0. Respondents who answered “don’t know” are omitted from the analysis.

To analyse this binary variable, we use a logistic functional form:

$$\Pr(y_{ij} = 1) = f(a_0 + \Delta PED_j \gamma_j + \boldsymbol{x}_{\boldsymbol{i}}' \boldsymbol{\beta}) + \epsilon_{ij}, \epsilon \sim N(0, \sigma^2) \quad (1)$$

We assume that the binary variable $y_{ij} \in [0,1]$ represents a continuous latent variable, $y_{ij}^*$, which is the likelihood that respondent *i* in climate region *j* expects drought prevalence to increase in the future. Since $y_{ij}^*$ is not observed, we assume that $y_{ij} = 1$ if $y_{ij}^* > 0$ and that the respondent believes that drought will increase.

To explore the determinants of drought expectations, the vector $\boldsymbol{x}$ includes several potential correlations, such as age, individual farming experience, family farming history, gender, and education level. These variables may affect an individual’s perceptions of recent drought (Goebbert et al. 2012) as well as describe his or her cultural disposition. Education in particular has been connected to belief in climate change as has political ideology (Hamilton and Stampone 2013; Hormsey et al 2016). Although we do not have data on political affiliation, we include other measures that are associated with either conservative or liberal perspectives, especially in the areas of environmental preferences. Specifically, we include measures of preference regarding habitat protection on both public and private land. We also include preferences regarding the right to hunt on public lands and an indicator of whether the respondent would decrease farm output if he or she could maintain the same level of profit. Farm profitability is included as an additional control together with an indicator of whether the farm employs staff.

Gender, education, family farming history, profitability, and farm labour are measured categorically; age and farming experience are continuous variables; and public/private land use preferences and farming output are measured on a 0-to-10 scale of agreement. The error term, $\epsilon$, is clustered on primary land use.

Our variable measuring drought experience is $\Delta PED_j$, defined as the percentage change of average 2015 PED from the long-run average PED in climate region $j$. To gauge the deviation of recent drought from average drought, we allow the definition of "long-run average" to vary from 1 year to 30. The characteristics of PED as a proxy for drought are explained in detail in the Data section below.

We also jointly consider the full set of responses to the question regarding drought expectations. To do so, we use an ordered logit model, a generalization of the binary outcome logit model for ordered data:

$$\Pr(belief_{ij} = w) = \Pr(k_{w-1} \leq \Delta PED_j \pi_{ij} + \boldsymbol{x}'_{ij}\boldsymbol{\phi} + u_{ij} \leq k_w) \quad (2)$$

where $k_0$ is assumed to be -∞, $k_w = \infty$, and $w$ indexes different beliefs about future drought ("decrease a lot", "decrease slightly," etc.). π and φ are estimated in the model. The error term, $u_{ij}$, is assumed to be logistically distributed.

Our final model evaluates planned land-use change (PLUC) in the near term using an ordered logit specification similar to the model in equation (2). Survey participants were asked if they planned to convert to a new land use in the subsequent two years:

$$\Pr(PLUC_{ij} = z) = \Pr(k_{z-1} \leq \Delta PED_j \delta_{ij} + y_{ij}\varphi_{ij} + \boldsymbol{x}'_{ij}\boldsymbol{\eta} + v_{pij} \leq k_z) \quad (3)$$

The dependent variable $PLUC_{ij}$ has three potential values: "Not at all likely," "possibly," and "very likely." $\phi$ and $\delta$ are estimated coefficients and $v$ is the error term.

*Survey of Rural Decision Makers*

The empirical analysis is based on the 2015 Survey of Rural Decision Makers (Brown 2015), a large, internet-based survey that covers both commercial production and lifestyle farming in all 16 regions in New Zealand. Developed during winter 2013 to inform agent-based models of land use in New Zealand, the survey consists of 288 questions, including detailed information on demographics; values; land use and land-use change; farm management; and climate outlook (Brown 2017). It was administered between August and November 2015.

The sampling strategy relied primarily on contacting farmers via email through the National Animal Identification and Tracing database, industry and sector group membership lists, and a list of individuals who responded to the 2013 Survey of Rural Decision Makers (Small, Brown, and Montes de Oca Munguia 2016). Industry and sector groups that circulated information about the survey among their members included Beef + Lamb New Zealand, the Farm Forestry Association, Federated Farmers, the Foundation for Arable Research, Horticulture New Zealand, New Zealand Wine, the QEII Charitable Trust, and Rural Women. Participation was incentivised via charitable contributions for each completed survey and prize draws. On average, the survey took 27 minutes to complete.

One criticism levied against online surveying is lack of accessibility, particularly for rural populations. However, approximately 80% of rural New Zealanders had home access to broadband in 2015 (a figure that is rapidly expanding under the government's Rural Broadband Initiative). In total, 2,839 respondents completed the survey, including 1,984 commercial farmers. The sample of commercial farmers closely approximates the farming population reported in the 2012 agricultural census by geography, industry, and farmer age (Statistics New Zealand 2013).

Our main variable of interest comes from a random subset of the respondents who were asked “Which of the following best describes how you personally expect the prevalence of drought to change by 2050?” Respondents chose from the following answers: “Decrease a lot”, “Decrease slightly”, “No change”, “Increase slightly”, “Increase a lot”, and “Don’t know”. After excluding 49 “don’t know” responses, our sample size is 561. This question is analysed both as a binary outcome (Equation (1)) and as an ordered outcome (Equation (2)) as described above.

Table 1 provides descriptive statistics for the dependent variables used in our analysis. The first model uses a binary dependent variable, where a 1 indicates a belief in increasing drought. This definition includes the two categories “Increase slightly” and “Increase a lot,” which combine for 65% of the respondents (Panel A). The second model is an ordered logit model and uses four categories.[4]

Analysis of planned land-use change (Equation (3)) uses variables related to the stated likelihood of land-use change within two years as the outcome variables while controlling for expectations of future drought. Specifically, respondents were asked, “How likely do you think each of the following is to happen on your farm during the next two years?”, where options included conversion, adding additional land to existing land uses, and intensification. For each option, respondents chose “Not very likely”, “Possibly”, or “Very likely”. Respondents were most likely to report that they intended to intensify current uses (Table 1, Panel B), with 33.63% selecting “Possibly” and 13.31% selecting “Very likely.” Conversion to new land uses was the least common intention, with 65.71% selecting “Not very likely”.

Table 2 shows the summary statistics for all explanatory variables. Respondents in the sample are generally older (57 years old, on average) men (75%) who have not earned a tertiary degree, who have been engaged in farming for 30 years, who believe that habitat for native species on public and private land should be protected, who believe the right to hunt on public land should be protected, and who would reduce output on their farms if the current level of profit could be maintained. Less than half of the farms are reported as being profitable (as opposed to being unprofitable or breaking even) and 27% currently lease land.

*Drought measures*

We use PED, a statistic measured by the National Institute of Water and Atmospheric Research (NIWA), to capture the magnitude and variation of past drought across 17 climate regions of New Zealand since 1948 (NIWA 2017c), providing both spatial and temporal variation. PED is a continuous non-negative variable based on the water-balance model and defined as potential evapotranspiration less actual evapotranspiration. This measure can be thought of as millimetres (mm) of water needed by vegetation to grow under no water shortage; a value of zero implies no water shortage. Because PED uses both water demanded by and water available through the environment, it is a robust measure of drought severity, especially in agricultural production (NIWA 2017a).

There are several alternate measures of drought. For instance, NIWA calculates a New Zealand Drought Index (NZDI), which is publicised on its New Zealand Drought Monitor website.[5] The NZDI incorporates PED and two other measures, the Standardised Precipitation Index and the Soil Moisture Deficit (NIWA 2017a). The NZDI is non-negative and continuous with values above 1.75 (1% of sample) indicating severe drought conditions (NIWA 2017a).

NZDI is available for each of the 66 districts in New Zealand on a daily time-step since 2007 (NIWA 2017b).[6]

Our drought variable of interest is the percentage difference in average 2015 PED from the long-run average PED, both measured at the regional level.[7] We define a yearly average PED as the average PED from January to June of that calendar year, corresponding to summer and autumn, the time when drought is generally most problematic for New Zealand farmers. Our long-run average measure of PED is defined as the mean of those annual values

Table 3 shows summary statistics for PED averaged across the 17 climate regions. It shows that PED was higher (i.e. drought more intensive) than the long-run average, where "long-run" varies from one year to 30. For example, PED was 29.69% higher in 2015 than over the previous 10 years and 57.77% higher than over the previous 30 years, on average. 2015 PED was lower than the 2-year average owing to an even more severe drought in 2013. In addition to evaluating long-term PED, we include the standard deviation of the 10-year long-run average PED as a control for long-run variability of drought within a region. Across the 17 climate regions, the average standard deviation of the 10-year long-run average PED is 9.31, ranging from 3.46 in West Coast to 14.48 in Auckland. [8]

## Results

We present the results of our logit (Equation (1)) and ordered logit (Equation (2)) models of drought expectations, our ordered logit (Equation (3)) model of planned land use change, and our robustness checks using different definitions of drought intensity.

*Models on Future Drought Expectations*

Table 4 presents estimates for equation (1), reporting average marginal effects. Column (1) shows results for the most parsimonious specification with only respondent age, gender, education, and farming experience as explanatory variables. We find that that male respondents ($p$<0.01) and respondents with long family histories of farming ($p$<0.01) are less likely to expect drought prevalence to increase. Conversely, respondents who have completed university education are more likely to expect the incidence of drought to increase ($p$<0.05). These results are qualitatively unchanged in column (2), which includes additional controls for attitudes toward habitat protection and farming sustainability. However, these results also show that preferences for protecting habitat on public land ($p$<0.10) and willingness to reduce farm output ($p$<0.10) (values that may be considered socially liberal in the New Zealand context) are associated with higher expectations of future drought. Conversely, preferences for maintaining the right to hunt on public land (a position that may be considered to be socially conservative in the New Zealand context) are negatively associated with expectations of future drought ($p$<0.10). These results hold with the addition of controls for profitability and primary water source (Column (3)), the former of which is negatively associated with expectations of future climate change ($p$<0.01).

Finally, column (4) adds the main variables of interest, the percentage deviation of PED from the 5-year average. To account for local variability in drought conditions over time, the standard deviation of PED is also included. Higher PED (i.e. more intensive drought relative to the 5-year average) is positively and significantly associated with higher expectations of future drought ($p$<0.01) while variability in long-run drought conditions are not statistically distinguishable from zero.[9]

Figure 1 shows the average marginal effect of deviation from trend in PED using the specification in column (4) but varying the reference period from 1 year to 30 years, keeping all else constant. 95% confidence intervals are also shown. The figure illustrates a concavity in the referenced period, with deviation from the 5-year trend having the greatest impact on the likelihood that respondents believe that drought will increase in the future.[10] This figure shows that recent trends (but not too recent) in drought are more salient than long-run trends for forming expectations regarding future drought.[11]

Table 5 presents the average marginal effects from the multivariate ordered logit model (Equation (2)) using the same specification as our binary logit model. We find similar results to our logit model, with covariate results robust to the inclusion of the PED variables. Results suggest that men ($p<0.01$) and people with considerable farming ancestry ($p<0.10$) are significantly less likely to expect future drought prevalence to increase, that those who believe that habitat should be protected on public land are more likely ($p<0.05$) to expect drought prevalence to increase, and that those who believe the right to hunt on public land should be protected are less likely ($p<0.01$) to expect drought prevalence to increase a lot. In this specification, the relationship between education and future drought expectation is not statistically distinguishable from zero.

As above, PED as measured as deviation from its 5-year trend is significantly ($p<0.01$) associated with expectations for future drought increase. The long-run standard deviation of PED is not significantly different from zero. To illustrate the sensitivity of these results over different reference periods, figure 2 shows the average marginal effect of the deviation in trend from one to 30 years. As above, there exists a non-linear effect of previous drought experiences on expectations of future drought prevalence, although the maximum shifts to 10 years. However, the difference in estimated coefficients between reference periods of five to ten years is negligible, suggesting again that farmers use a relatively short reference period when evaluating the intensity of recent drought. Also note that the 95% confidence intervals in this figure are significant across the full range of estimates. Thus, a 10-percentage point increase in deviation of the average 2015 PED from the 10-year average PED leads to a decrease in likelihood of expecting drought prevalence to decrease (–0.4%) or not change (–3.9%) and an increase in like likelihood of expecting drought prevalence to increase slightly (2%) or a lot (2.3%), *ceteris paribus*.

*Future Drought Expectations, Age, and Farming Experience*

The previous analysis indicates that recent drought experiences are correlated with respondents' expectations of future drought. Since past research has found that belief in climate change varies across several identifiable characteristics including age (Hornsey et al. 2016), we introduce an interaction term between PED and age, split into 10-year bins (Table 6). To conserve space, we only report the full marginal effect of the difference in PED for different age groups. The significance and magnitude of the other coefficients are directly comparable to those reported in table 4. The columns in the table differ by the number of years over with the long-term average PED is evaluated. The rows vary over the average marginal effects of different age groups interacted with the PED average.

The most striking effects occur in middle-aged farmers. Compared with other age groups, farmers between 40 and 60 years of age are more likely to change their expectations regarding drought after experiencing abnormal drought conditions. All these marginal effects are positive, suggesting that drought conditions revised those farmers' beliefs in the effects of climate change upward.[12]

*Models of Land-Use Change*

Table 7 presents the average marginal effects for our measures of three land-use changes per equation (3). A dummy indicating expectations of higher future drought is included as an explanatory variable.

Age is negatively correlated with increasing likelihood of converting to new land uses, allocating more land to current uses, and intensifying current land uses within the next 2 years, while men and those with preferences for habitat conservation are disproportionately likely to convert to new land uses and allocate more land to current uses.[13]

Expectations of future drought are positively correlated with converting to new land uses but are not correlated with allocating more land to current uses or to intensification. This result is roughly consistent with the results of Mase, Gramig, and Prokopy (2017), who find that climate change beliefs are associated with adaptation as opposed to more marginal change.

*Robustness*

We check the robustness of our primary results using two definitions of drought: NZDI, a less aggregated, more comprehensive (but shorter time series) drought index than PED; and regional PED averaged over the 6 months before a respondent submitted the survey (as opposed to January–June, the 6 months that are usually most critical for rainfall in New Zealand agriculture).[14] In each case, drought is again measured as the percentage deviation from long-run trend.

Figure 3 plots the average marginal effects for these alternate measures, with differences in the reference period along the X-axis. The dependent variable in each of these regressions is the binary variable for drought expectations, similar to equation (1). Again, the trend is increasing, with a 10-percentge point increase in PED relative to the 8-year historical average being associated with a 2.8% greater likelihood of expecting that drought will increase by 2050. These results support our previous findings that farmers reference past experiences of drought when evaluating future climate change.

For drought in the 6 months before the survey was completed, the point estimates peak at 6 years with a subtler tailing off.[15] We estimate that a 10-percentage point increase in average 2015 PED relative to the previous 6-year average PED is associated with a 0.036% increase in expecting drought prevalence to increase by 2050. While this estimate is roughly one-tenth the size of the maximum effect discussed in Section 3.1, the 6-month window included wet winter months for many survey respondents. This result broadly echoes those of Li, Johnson, and Zaval (2011), in which weather on the day on which the survey was administered is shown to impact on belief in anthropogenic climate change.

**Conclusion**

Across models, we find that women and those who prefer habitat conservation are disproportionally likely to expect drought prevalence to increase by 2050, while those who wish to maintain the right to hunt on public land are less likely to expect drought prevalence to increase, *ceteris paribus*. These findings are consistent with the broader literature in which women and those who identify as being politically liberal are more likely to believe in climate change, while those who identify as being politically conservative are less likely to believe in climate change (e.g. Hornsey et al. 2016). Due to differences in social norms across countries, these results are noteworthy in themselves. Findings that men and those with socially conservative views disproportionately believe that drought will not change are similar to those found in Australia and the US (Wheeler, Zou, and Bjornlund 2013), for instance. Our results on the determinants of drought expectations also suggest that some international lessons learned on communicating natural-hazard risk information might be applied in New Zealand and that common beliefs related to social leanings might be used to tailor messages to different areas and demographics.

Our results also suggest that the intensity of drought experienced by respondents relative to trend is strongly correlated with expectations of future drought. Moreover, we find a distinct concavity in the referenced period, with deviations from trend over the previous 5–10 years having the greatest impact on expectations of future drought; that is, while the 2015 drought was severe by any measure, its relative intensity compared with the 30-year average exceeded its intensity relative to the 1-year average, indicating that farmers reference more recent drought experiences rather than longer time trends. These findings are robust to different definitions of "drought", including both the time of year at which drought is measured (i.e. the dry part of the year vis-à-vis the 6 months immediately preceding the survey) and the specific way in which it is measured (i.e. PED vis-à-vis NZDI).

Under the IPCC Fifth Assessment, current modelling projections for New Zealand suggest a 0.8°C increase in temperature by 2040 and both more extreme rainfall events and increased drought severity. To accommodate these future changes, New Zealand's Ministry for the Environment has published guidance on climate change adaptation for local governments that emphasises programs to promote voluntary land-use conversion.[16] Our results indicate that land-use conversion will accelerate with increased exposure to drought. At the same time, the finding that individuals reference the previous 5–10 years as opposed to the long-term historical record may result in a deceleration of climate-change adaptation as farmers reference moving averages, i.e. as drought becomes the "new normal". These results are consistent with Carlton et al. (2016), who caution that "policy designs that rely on increasing risk perceptions to motivate action on climate change may be overestimating the effects of extreme events on feeling at risk".

Unfortunately, our data do not explore the mechanisms underlying changing expectations of future drought. For example, survey respondents may believe that the frequency of drought will increase in the future, that the severity of drought will increase in the future, or both. These beliefs could plausibly influence planned responses and adaptations. A promising area of future research is thus understanding these distinct components of climate-change beliefs.

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[1] Perhaps surprisingly, expectations regarding future climate change are also associated with natural disasters that are independent of climate such as earthquakes (Kung and Chen 2012) and landslides (Lin, Shaw, and Ho 2008).

[2] However, belief in climate change may also distort perceptions of weather, with those who do not believe in climate change being less likely to perceive abnormal weather conditions (Myers et al. 2012; Howe and Leiserowitz 2013).

[3] The survey does not ask more specifically about human-induced climate change. For planning purposes, this divorces the cause of climate change from planning considerations, and may be less politically charged than asking about sources of climate change.

[4] "Decrease a lot" and "Decrease slightly" were combined due to the low number of respondents who selected the former.

[5] https://www.niwa.co.nz/climate/information-and-resources/drought-monitor

[6] While this measure is more comprehensive than PED alone, it is only available for recent years.

[7] Since our outcome variables are defined in terms of relative expectations of future drought and land-use change, defining our key explanatory variable in terms of relative drought severity better identifies the frame of reference that respondents use for past drought experience.

[8] See Table A1 in Appendix for the average and standard deviation of PED by climate region.

[9] Although we specify the 10-year standard deviation of PED to measure local drought variability, point estimates are not statistically significant for a wide range of time periods.

[10] Inclusion of a second-order quadratic of our key drought variable yields no significant effects.

[11] This short reference period is interesting, given that PED in 2015 deviated more from the 30-year average than from the average over the previous 5–10 years (see Table A1).

[12] Results for experience are analogous, showing that farmers with 20–40 years of farming experience are the most likely to change their minds about future drought expectations after experiencing drought conditions out of the normal range.

[13] Among respondents who reported intentions to convert to new land uses, 16% reported that they planned to convert to cattle, 16% reported that they planned to convert to hay, and 14.3% reported that they planned to convert to dairy runoffs. Of those who reported intentions to allocate more land to current land uses, 30% reported that they planned to allocate more land to sheep and/or beef, 18% reported that they planned to allocate more land to cattle, and 15% reported that they planned to allocate more land to fruit growing. Of those who reported intentions to intensify current land uses within the next 2 years, 42% reported that they planned to intensify sheep and/or beef, 17.6% reported that they planned to intensify cattle, and 12% reported that they planned to intensify grazing for sheep, beef, and other cattle not owned by the farm.

[14] Including dummies for the month of submission has no discernible effect on our results.

[15] See figure A1 in appendix.

[16]See http://www.mfe.govt.nz/publications/climate-change/coastal-hazards-and-climate-change-guidance-local-government and http://www.mfe.govt.nz/climate-change/what-government-doing/adapting-climate-change

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**Table 1. Summary Statistics of Dependent Variables**

| Panel A | Expectation of Drought Prevalence by 2050 (N = 561) | | | | |
|---|---|---|---|---|---|
| | Decrease a lot | Decrease slightly | No change | Increase slightly | Increase a lot |
| Percent of respondents | 0.36 | 1.6 | 32.98 | 51.69 | 13.37 |

| Panel B | Likelihood of Land-Use Changes within 2 Years (Percent of Respondents) | | |
|---|---|---|---|
| | Not very likely | Possibly | Very likely |
| Plan to convert to or add new land uses (N=557) | 65.71 | 25.49 | 8.80 |
| Plan to allocate more land to current uses (N=556) | 64.39 | 24.82 | 10.79 |
| Plan to intensify current land uses (N=556) | 53.06 | 33.63 | 13.31 |

Notes: Data from the 2015 Survey of Rural Decision Makers cover all New Zealand regions. The ordered logit model has four levels: Decrease a lot or slightly, No change, Increase slightly, and Increase a lot. The logit model has two levels: Decrease a lot, decrease slightly, or No change vs Increase slightly or Increase a lot. Ordered logit regression is used for likelihood of land-use change models. The binary version of drought expectation is included as an explanatory variable in land-use change models. Total counts are limited to sub-samples used for analysis. Sample proportions are similar to proportions in full samples.

**Table 2. Summary Statistics of Covariates**

| Variables | Average | Standard Deviation | Minimum | Maximum |
|---|---|---|---|---|
| Age (years) | 56.97 | 11.56 | 24 | 85 |
| Male (=1) | 0.75 | 0.43 | 0 | 1 |
| Bachelor's degree or more (=1) | 0.40 | 0.49 | 0 | 1 |
| Farming for 6 generations or more (=1) | 0.06 | 0.24 | 0 | 1 |
| Maximum farming experience (years) | 30.01 | 14.79 | 0 | 65 |
| Agreement: habitat on public land should be protected. | 7.84 | 1.96 | 0 | 10 |
| Agreement: habitat on private land should be protected. | 6.99 | 2.23 | 0 | 10 |
| Agreement: right to hunt on public land. | 7.40 | 2.24 | 0 | 10 |
| I would reduce farm output if I could maintain same level of profit. | 6.49 | 2.40 | 0 | 10 |
| Farm is profitable (=1) | 0.47 | 0.50 | 0 | 1 |
| Currently lease land (=1) | 0.27 | 0.44 | 0 | 1 |
| Use ground water (=1) | 0.64 | 0.48 | 0 | 1 |
| Use surface water (=1) | 0.41 | 0.49 | 0 | 1 |
| Use rain water (=1) | 0.50 | 0.50 | 0 | 1 |

Notes: Data from 2015 Survey of Rural Decision Makers cover all New Zealand regions. Education level, farming experience, and farming generations are recorded as the maximum for the household. Maximum farming experience was defined as the number of years in farming after age 18. The three 'Agreement' questions and reduction in farm output question were defined on a scale from 0 (strongly disagree) to 10 (strongly agree). Maximum farming experience is measured in years since age 18. Summary statistics are limited to the sample used in analysis. The restricted sample is not statistically different from full sample of commercial farmers.

**Table 3. Potential Evapotranspiration Deficit Summary Statistics**

| Number of Previous Years | Percent Difference of 2015 Average PED from Long-Run Average PED | | | |
|---|---|---|---|---|
| | Minimum | Average | Maximum | Standard Deviation |
| 1 | -37.56 | 13.76 | 53.23 | 25.11 |
| 2 | -61.91 | -1.33 | 46.43 | 29.70 |
| 3 | -47.26 | 20.98 | 56.44 | 29.15 |
| 4 | -29.67 | 30.41 | 60.29 | 24.93 |
| 5 | -21.34 | 26.83 | 51.68 | 20.62 |
| 6 | -13.87 | 28.08 | 52.44 | 18.33 |
| 7 | -6.83 | 23.92 | 46.34 | 17.83 |
| 8 | -3.17 | 24.63 | 48.09 | 15.91 |
| 9 | 2.50 | 27.46 | 48.66 | 14.00 |
| 10 | 9.15 | 29.69 | 53.93 | 13.00 |
| 11 | 9.17 | 35.24 | 62.03 | 14.58 |
| 12 | 5.96 | 34.36 | 59.57 | 14.92 |
| 13 | 5.89 | 38.83 | 67.75 | 16.14 |
| 14 | 2.75 | 37.53 | 57.88 | 15.42 |
| 15 | 3.07 | 39.01 | 63.77 | 16.11 |
| 16 | -4.47 | 37.81 | 60.31 | 17.22 |
| 17 | -3.55 | 36.31 | 60.96 | 16.13 |
| 18 | -3.04 | 38.93 | 64.44 | 16.62 |
| 19 | -1.15 | 42.66 | 72.43 | 17.75 |
| 20 | -2.48 | 44.44 | 77.60 | 18.89 |

| | | | | |
|---|---|---|---|---|
| 21 | 1.72 | 45.59 | 80.08 | 18.30 |
| 22 | 4.49 | 47.46 | 83.48 | 18.90 |
| 23 | 6.19 | 49.99 | 89.79 | 20.36 |
| 24 | 9.39 | 51.64 | 94.53 | 21.25 |
| 25 | 7.89 | 51.62 | 95.23 | 21.92 |
| 26 | 9.31 | 52.75 | 101.91 | 22.20 |
| 27 | 10.82 | 53.57 | 104.90 | 22.80 |
| 28 | 13.63 | 54.19 | 103.88 | 22.90 |
| 29 | 14.58 | 57.20 | 110.60 | 24.49 |
| 30 | 15.46 | 57.77 | 114.77 | 25.37 |

Notes: PED data from NIWA for 17 climate regions. PED is measured as mm of water needed to supplement current precipitation to maintain vegetation growth under no water scarcity. Percent difference is measured in percentage points. Long-run average PED is calculated by climate region as the average of the January to June average PED.

**Table 4. Average Marginal Effects from Logit Regression on Covariates and One-Year Deviation**

| | Dependent Variable: Expect the prevalence of drought to increase = 1 | | | |
|---|---|---|---|---|
| Independent Variables | (1) | (2) | (3) | Last 5 years |
| Age (years) | 0.00312 | 0.00280 | 0.00249 | 0.00199 |
| | (0.00213) | (0.00203) | (0.00208) | (0.00178) |
| Male (=1) | -0.170*** | -0.157*** | -0.153*** | -0.170*** |
| | (0.0318) | (0.0335) | (0.0319) | (0.0339) |
| Bachelor's degree or more (=1) | 0.0927** | 0.0894** | 0.0902** | 0.0863** |
| | (0.0427) | (0.0414) | (0.0394) | (0.0386) |
| Farming for 6 generations or more (=1) | -0.145*** | -0.139*** | -0.147*** | -0.149*** |
| | (0.0425) | (0.0456) | (0.0460) | (0.0447) |
| Maximum farming experience (years) | -0.00233 | -0.00208 | -0.00175 | -0.00147 |
| | (0.00188) | (0.00175) | (0.00194) | (0.00188) |
| Agreement: habitat on public land | | 0.0169* | 0.0166* | 0.0175* |
| should be protected | | (0.0102) | (0.0108) | (0.00974) |
| Agreement: habitat on private land | | 0.00573 | 0.00586 | 0.00515 |
| should be protected | | (0.0112) | (0.0106) | (0.0102) |
| Agreement: right to hunt on public land | | -0.0133* | -0.0143* | -0.0153** |
| | | (0.00735) | (0.00731) | (0.00775) |
| I would reduce farm output if I could | | 0.0107 | 0.00881 | 0.00816 |
| maintain same level of profit. | | (0.00623) | (0.00575) | (0.00619) |

| | | | | |
|---|---|---|---|---|
| Farm is profitable (=1) | | | -0.0989*** | -0.104*** |
| | | | (0.0344) | (0.0313) |
| Use ground water (=1) | | | 0.0336 | 0.0311 |
| | | | (0.0466) | (0.0469) |
| Use surface water (=1) | | | 0.0596 | 0.0577 |
| | | | (0.0499) | (0.0480) |
| Use rain water (=1) | | | -0.0406 | -0.0327 |
| | | | (0.0335) | (0.0348) |
| Percent difference of 2015 average PED from 5-year long-run average PED (pp) | | | | 0.00352*** |
| | | | | (0.000583) |
| 10-year long-run average PED standard deviation | | | | 0.00320 |
| | | | | (0.00420) |
| Observations | 561 | 561 | 561 | 561 |

Notes: Standard errors are shown in parentheses. PED data from NIWA covers 17 climate regions. Data from the 2015 Survey of Rural Decision Makers cover all New Zealand regions and were matched to PED data via districts. Models estimate average marginal effects of the probability that respondents expect the prevalence of drought to increase slightly or to increase a lot by 2050. Base values of the dependent variable include respondents who expect the prevalence of drought to decrease a lot, decrease slightly, or not change by 2050. Standard errors clustered by primary land use/farming activity. Asterisks *** indicate $p < 0.01$; ** indicate $p < 0.05$; and * indicates $p < 0.10$.

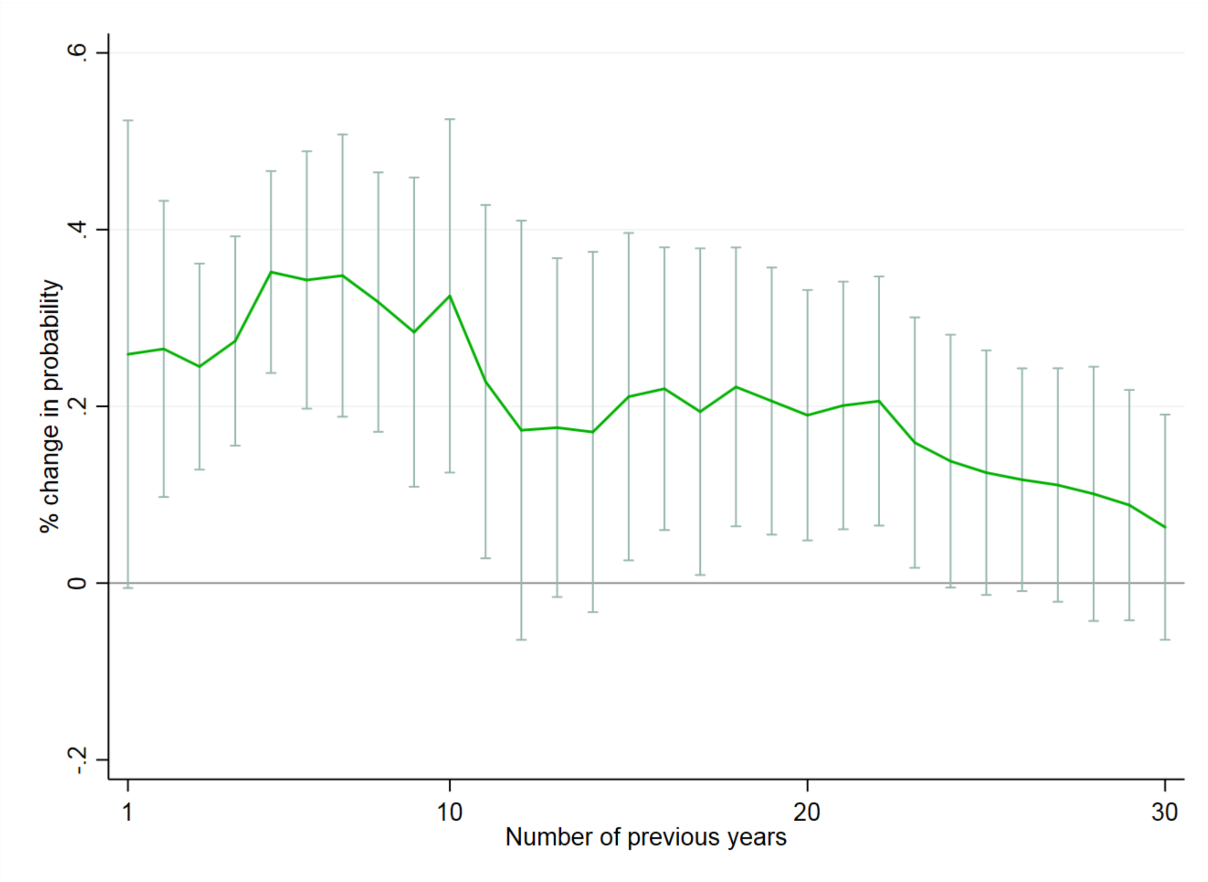


**Figure 1. Average marginal effects from logit regression of drought prevalence expectation**

Notes: This figure shows the average marginal effects and 95% confidence intervals for the percent change in average 2015 PED from the long-run average PED, estimated in a multi-variate logit regression of the expectation of future drought prevalence by 2050. Long-run average PED calculated per year from average PED from January to June of that year. Data are from NIWA and the Survey of Rural Decision Makers 2015. The model used 561 observations.

**Table 5. Average Marginal Effects from Ordered Logit Regression**

| | Dependent Variable: Expectation of prevalence of drought by 2050 | | | |
|---|---|---|---|---|
| Independent Variables | Decrease | No change | Increase slightly | Increase a lot |
| Age (years) | -0.0001 | -0.00098 | 0.0005 | 0.00058 |
| | (0.00015) | (0.00148) | (0.00077) | (0.00086) |
| Male (=1) | 0.0126*** | 0.1475*** | -0.0578*** | -0.1023*** |
| | (0.00353) | (0.02544) | (0.01175) | (0.01953) |
| Bachelor's degree or more (=1) | -0.0030 | -0.0302 | 0.0153 | 0.01798 |
| | (0.00322) | (0.03728) | (0.01801) | (0.02254) |
| Farming for 6 generations or more (=1) | 0.0133* | 0.1071** | -0.0689*** | -0.0515** |
| | (0.00711) | (0.04887) | (0.03558) | (0.02035) |
| Maximum farming experience (years) | 0.00013 | 0.0013 | -0.00067 | -0.00076 |
| | (0.00018) | (0.00170) | (0.00089) | (0.001) |
| Agreement: habitat on public land should be protected | -0.0022** | -0.0218** | 0.0112** | 0.0128** |
| | (0.00104) | (0.00923) | (0.00469) | (0.00562) |
| Agreement: habitat on private land should be protected | -0.0011 | -0.0107 | 0.0055 | 0.0063 |
| | (0.00101) | (0.00894) | (0.00466) | (0.00532) |
| Agreement: right to hunt on public land | 0.0018*** | 0.01799*** | -0.0093*** | -0.0106*** |
| | (0.00068) | (0.00482) | (0.00262) | (0.00296) |
| I would reduce farm output if I could maintain same level of profit. | -0.0011* | -0.0109** | 0.0056** | 0.0064** |
| | (0.0006) | (0.00466) | (0.00245) | (0.00284) |

| | | | | |
|---|---|---|---|---|
| Farm is profitable (=1) | 0.0085*** | 0.0847*** | -0.0447*** | -0.0484*** |
| | (0.00298) | (0.02608) | (0.01417) | (0.01514) |
| Use ground water (=1) | 0.0019 | 0.019 | -0.0096 | -0.0113 |
| | (0.00317) | (0.03187) | (0.01584) | (0.0192) |
| Use surface water (=1) | -0.0038 | -0.0379 | 0.0191 | 0.0227 |
| | (0.00371) | (0.03471) | (0.01723) | (0.02124) |
| Use rain water (=1) | 0.0045** | 0.0444** | -0.0229** | -0.02597** |
| | (0.00227) | (0.01796) | (0.00971) | (0.01065) |
| Percent difference of 2015 average PED from 5-year long-run average PED (pp) | -0.00031*** | -0.00303*** | 0.00156*** | 0.00178*** |
| | (0.00009) | (0.00051) | (0.00033) | (0.0003) |
| 10-year long-run average PED standard deviation | -0.00033 | -0.0034 | 0.0017 | 0.0019 |
| | (0.00044) | (0.00441 | (0.0023) | (0.00255) |
| Observations | 561 | | | |

Notes: Standard errors are shown in parentheses. PED data from NIWA covers 17 climate regions. Data from the 2015 Survey of Rural Decision Makers cover all New Zealand regions and were matched to PED data via districts. Models estimate average marginal effects of the probability that respondents expect the prevalence of drought to decrease, not change, increase slightly, or increase a lot by 2050 using a multi-variate ordered logit. Standard errors are clustered by primary land use/farming activity. Asterisks *** indicate $p < 0.01$; ** indicate $p < 0.05$; and * indicates $p < 0.10$.

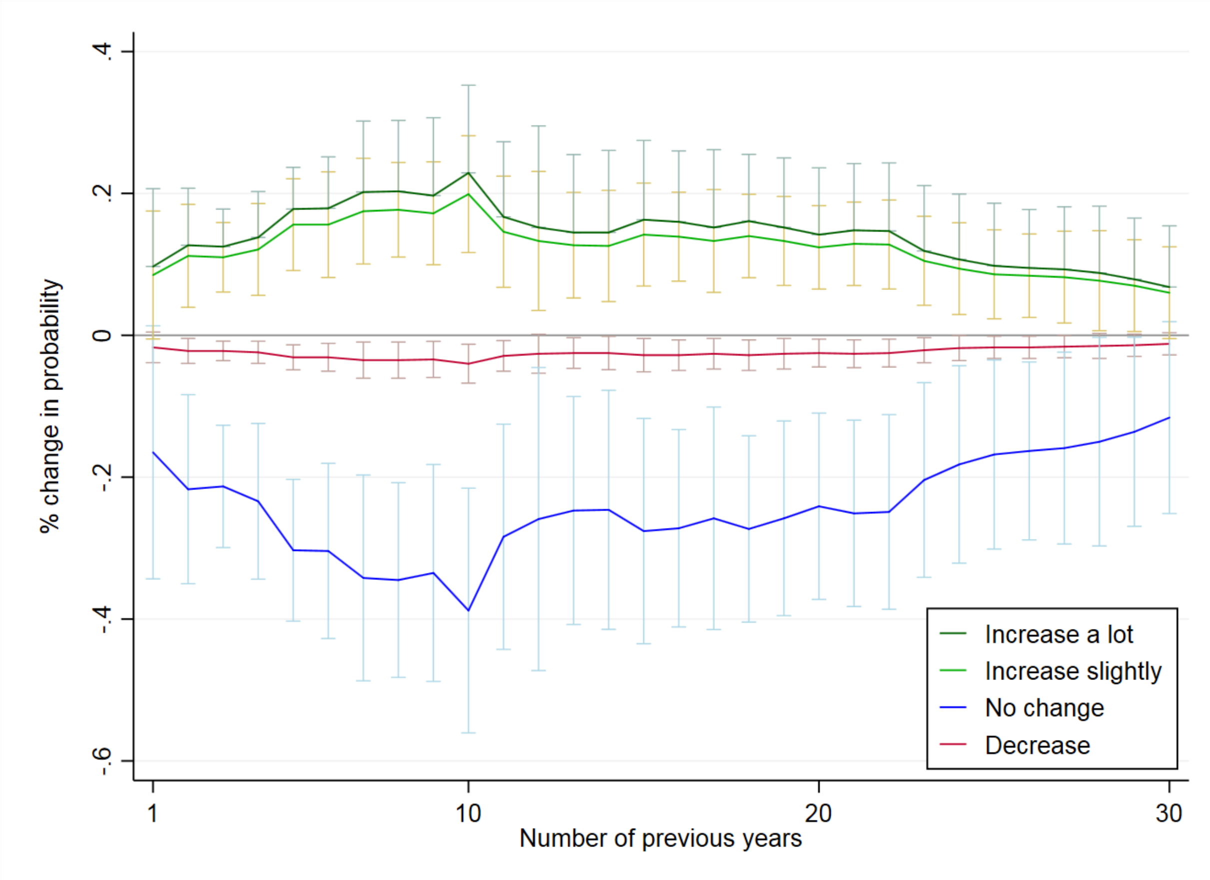


**Figure 2. Average marginal effects from ordered logit regression of drought prevalence expectation**

Notes: This figure shows the average marginal effects and 95% confidence intervals for the percent change in average 2015 PED from the long-run average PED, estimated in a multi-variate logit regression of the expectation of future drought prevalence by 2050. Data are derived from NIWA and the 2015 Survey of Rural Decision Makers. The model used 561 observations.

**TABLE 6. Average Marginal Effects of Deviations from Long Run Average PED, Interacted with Age**

| | Dependent Variable: Expect the prevalence of drought to increase = 1 | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Age | Previous 1 Year | Previous 2 Years | Previous 3 Years | Previous 4 Years | Previous 5 Years | Previous 6 Years | Previous 7 Years | Previous 8 Years | Previous 9 Years | Previous 10 Years |
| 31-40 | 0.00064 | 0.00137 | 0.00216 | 0.00232 | 0.00409 | 0.00451 | 0.00423 | 0.00469 | 0.00558 | 0.00531 |
| | (0.00353) | (0.00284) | (0.00207) | (0.00258) | (0.00267) | (0.00315) | (0.00281) | (0.00311) | (0.00352) | (0.00418) |
| 41-50 | 0.00335** | 0.00496*** | 0.00558*** | 0.00708*** | 0.00784*** | 0.00796*** | 0.00860*** | 0.00860*** | 0.00824*** | 0.00889*** |
| | (0.00150) | (0.00118) | (0.00112) | (0.00120) | (0.00164) | (0.00190) | (0.00173) | (0.00178) | (0.00197) | (0.00225) |
| 51-60 | 0.00243 | 0.00250** | 0.00345*** | 0.00387*** | 0.00466*** | 0.00449** | 0.00488*** | 0.00499*** | 0.00478** | 0.00474** |
| | (0.00157) | (0.00126) | (0.00114) | (0.00144) | (0.00153) | (0.00184) | (0.00177) | (0.00185) | (0.00206) | (0.00224) |
| 61-70 | 0.00302* | 0.00248 | 0.00106 | 0.00077 | 0.00148 | 0.00136 | 0.000832 | 0.000408 | -4.54e-05 | 0.00138 |
| | (0.00175) | (0.00193) | (0.00158) | (0.00179) | (0.00214) | (0.00258) | (0.00280) | (0.00288) | (0.00311) | (0.00350) |
| 71 + | 0.00244 | 0.00203 | 0.00121 | 0.00103 | 0.00138 | 0.00103 | 0.00225 | 0.00158 | 0.00094 | 0.00118 |
| | (0.00322) | (0.00235) | (0.00253) | (0.00227) | (0.00247) | (0.00256) | (0.00394) | (0.00434) | (0.00466) | (0.00443) |
| Observations | 556 | 556 | 556 | 556 | 556 | 556 | 556 | 556 | 556 | 556 |

Notes: Standard errors are shown in parentheses. PED data from NIWA cover 17 climate regions. Data from the 2015 Survey of Rural Decision Makers cover all New Zealand regions and were matched to PED data via districts. Models estimate average marginal effects of probability that respondents expect the prevalence of drought to increase slightly or increase a lot by 2050. Base value of dependent variables includes respondents who expect the prevalence of drought to decrease a lot, decrease slight, or not change by 2050. Asterisks *** indicate $p < 0.01$; ** indicate $p < 0.05$; and * indicates $p < 0.10$.

**Table 7. Average Marginal Effects from Future Land Use Change**

| | Dependent variable: Likelihood of land use change within next 2 years | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Converting land to new uses | | | Allocating more land to current uses | | | Intensifying current land uses | | |
| | (1) | | | (2) | | | (3) | | |
| Independent Variables | Not likely | Possibly | Very likely | Not likely | Possibly | Very likely | Not likely | Possibly | Very likely |
| Age (years) | 0.0096*** | -0.00602*** | -0.0036*** | 0.0093*** | -0.0052*** | -0.0041*** | 0.0099*** | -0.0052*** | -0.0047* |
| | (0.00224) | (0.00153) | (0.00109) | (0.0019) | (0.00115) | (0.00098) | (0.00362) | (0.00128) | (0.00243) |
| Male (=1) | -0.0877* | 0.0568 | 0.0309** | -0.1554*** | 0.0935** | 0.0619*** | -0.0551 | 0.0297 | 0.0255 |
| | (0.04787) | (0.03656) | (0.01222) | (0.05354) | (0.03854) | (0.01715) | (0.04717) | (0.02503) | (0.0228) |
| Bachelor's degree or | -0.0082 | 0.0052 | 0.0031 | -0.0216 | 0.0121 | 0.0095 | 0.0043 | -0.0022 | -0.0021 |
| more (=1) | (0.03356) | (0.02129) | (0.01229) | (0.03703) | (0.02111) | (0.01598) | (0.03261) | (0.01711) | (0.0155) |
| Farming for 6 generations | -0.0171 | 0.0107 | 0.0065 | -0.1329*** | 0.0665*** | 0.0664*** | -0.0818 | 0.0386 | 0.0432 |
| or more (=1) | (0.06125) | (0.03738) | (0.02392) | (0.04672) | (0.02337) | (0.02556) | (0.08334) | (0.03603) | (0.04844) |
| Maximum farming | -0.0012 | 0.0007 | 0.0004 | 0.0003 | -0.0002 | -0.0002 | -0.0019 | 0.0010 | 0.0009 |
| experience (years) | (0.00161) | (0.00101) | (0.00061) | (0.0019) | (0.00106) | (0.00085) | (0.00167) | (0.00079) | (0.00089) |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Agreement: habitat on public land should be | 0.0183* | -0.0115 | -0.0068* | 0.0088 | -0.0049 | -0.0039 | -0.0005 | 0.0003 | 0.0003 |
| protected | (0.01111) | (0.00733) | (0.00409) | (0.00791) | (0.00468) | (0.00326) | (0.01312) | (0.00686) | (0.00626) |
| Agreement: habitat on private land should be | -0.0209*** | 0.0132** | 0.0077** | -0.0078* | 0.0044* | 0.0034* | 0.0010 | -0.0005 | -0.0005 |
| protected | (0.00808) | (0.00551) | (0.00311) | (0.00422) | (0.00227) | (0.00202) | (0.01514) | (0.00795) | (0.00719) |
| Agreement: right to hunt | 0.00001 | 0.00001 | 0.0 | -0.0025 | 0.0014 | 0.0011 | -0.0122 | 0.0063 | 0.0058* |
| on public land | (0.00882) | (0.00555) | (0.00327) | (0.01016) | (0.00572) | (0.00444) | (0.00748) | (0.00432) | (0.00338) |
| I would reduce farm output if I could maintain | 0.0071 | -0.0045 | -0.0026 | 0.0145** | -0.0081** | -0.0064** | 0.0103 | -0.0053 | -0.0049 |
| same level of profit. | (0.0071) | (0.0048) | (0.00235) | (0.00632) | (0.00373) | (0.00276) | (0.00713) | (0.00335) | (0.00391) |
| Farm is profitable (=1) | -0.0147 | 0.0092 | 0.0054 | -0.0598* | 0.0336* | 0.0262* | 0.0451 | -0.0236 | -0.0215 |
| | (0.03059) | (0.01969) | (0.01096) | (0.03093) | (0.01741) | (0.01413) | (0.03875) | (0.01858) | (0.0206) |
| Currently lease land (=1) | -0.0673 | 0.0418* | 0.0255 | 0.0404 | -0.0229 | -0.0175 | -0.0590 | 0.0299 | 0.0291 |
| | (0.04363) | (0.02279) | (0.02113) | (0.0663) | (0.03946) | (0.02691) | (0.03881) | (0.01905) | (0.02085) |
| Use ground water (=1) | -0.0182 | 0.0115 | 0.0067 | -0.0004 | 0.0002 | 0.0002 | 0.0370 | -0.0191 | -0.0179 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | (0.03417) | (0.02197) | (0.0123) | (0.0304) | (0.01702) | (0.01338) | (0.05851) | (0.02854) | (0.03017) |
| Use surface water (=1) | -0.0544 | 0.0341 | 0.0203 | -0.1324*** | 0.0740*** | 0.0583*** | -0.0496 | 0.0257 | 0.0239 |
| | (0.04001) | (0.02694) | (0.01371) | (0.03687) | (0.02298) | (0.01643) | (0.04952) | (0.02546) | (0.02464) |
| Use rain water (=1) | 0.0000 | 0.0000 | 0.0000 | -0.0509 | 0.0286 | 0.0224 | -0.0862** | 0.0452* | 0.0410*** |
| | (0.03071) | (0.01933) | (0.01138) | (0.03751) | (0.0222) | (0.01564) | (0.03766) | (0.02396) | (0.01559) |
| Drought prevalence will | -0.0331* | 0.0210* | 0.0121* | -0.0055 | 0.0031 | 0.0024 | 0.0328 | -0.0169 | -0.0159 |
| increase (=1) | (0.0183) | (0.01202) | (0.00688) | (0.0418) | (0.02333) | (0.01848) | (0.02531) | (0.01393) | (0.01186) |
| Observations | 557 | | | 556 | | | 556 | | |

Notes: Standard errors are shown in parentheses. Data from the 2015 Survey of Rural Decision Makers cover all New Zealand regions. Models estimate Average Marginal Effects of the probability that respondents expect to change their land use within the next 2 years using an ordered logit regression. Standard errors are clustered at the primary land use/farming activity. Asterisks *** indicate $p < 0.01$; ** indicate $p < 0.05$; and * indicates $p < 0.10$.

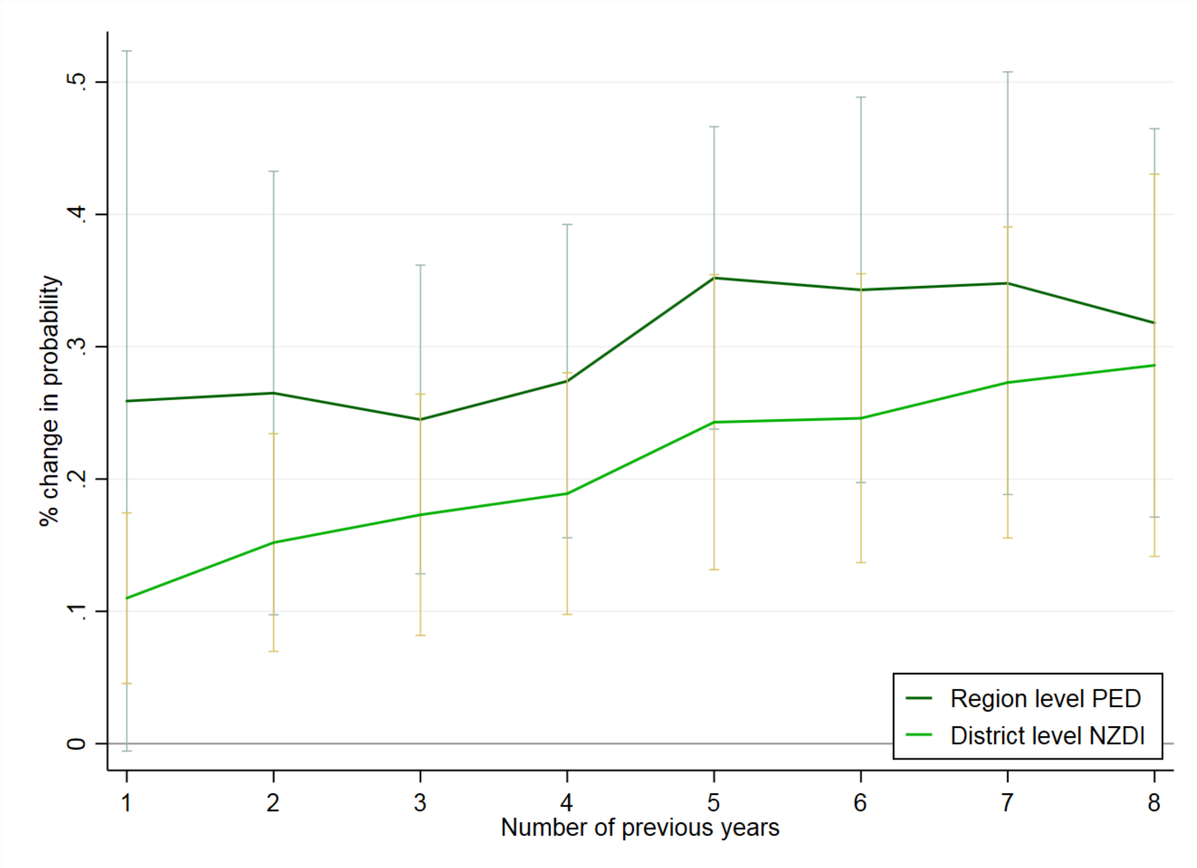


**Figure 3. Average marginal effects of deviations from 1 to 8-year long run average NZDI at the district level and long run average PED at the region level**

Notes: This figure shows the average marginal effects and 95% confidence intervals for A) the percent change in average 2015 PED from the long-run average PED at the region level, and B) the percent change in average 2015 NZDI from the long-run average NZDI at the district level. Both are estimated in a multi-variate logit regression of the expectation of future drought prevalence by 2050. Data are from NIWA and the Survey of Rural Decision Makers 2015. These models used 561 observations.

## Appendix

**Table A1. Potential Evapotranspiration Deficit Average and Standard Deviation by Climate Region**

| | Average PED for a given year | | | | | | | Number of previous years in long-run average PED | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Region | 2015 | 2010 | 2005 | 2000 | 1995 | 1990 | 1985 | 5 | 10 | 15 | 20 | 25 | 30 |
| Northland | 37.42 | 50.43 | 41.28 | 25.57 | 15.65 | 29.96 | 14.61 | 36.62 | 32.07 | 28.01 | 26.62 | 27.68 | 26.24 |
| | (38.66) | (48.09) | (33.92) | (26.06) | (22.11) | (33.3) | (22.2) | (16.33) | (13.71) | (12.84) | (12.06) | (11.3) | (11.11) |
| Auckland | 46.62 | 52.82 | 39.77 | 39.58 | 23.26 | 41.15 | 18.42 | 37.46 | 36.48 | 31.83 | 31.34 | 32.83 | 31.69 |
| | (57.7) | (46.24) | (36.21) | (42.8) | (34.5) | (49.32) | (21.92) | (21.17) | (14.49) | (14.49) | (12.91) | (12.12) | (11.67) |
| Waikato | 37.73 | 33.59 | 28.71 | 29.26 | 17.46 | 25.10 | 10.63 | 31.30 | 29.80 | 25.88 | 24.89 | 24.20 | 22.75 |
| | (48.02) | (33.27) | (26.39) | (36.33) | (29.08) | (28.9) | (17.04) | (17.6) | (13.18) | (12.55) | (11.46) | (10.64) | (10.6) |
| Bay of Plenty | 37.62 | 31.32 | 30.54 | 25.72 | 16.16 | 16.87 | 9.04 | 29.62 | 28.33 | 25.61 | 23.93 | 22.41 | 21.16 |
| | (49.97) | (35.58) | (29.22) | (33.75) | (22.27) | (17.87) | (11.21) | (18.05) | (13.07) | (11.49) | (11.37) | (10.93) | (10.87) |
| King Country / | 20.75 | 13.07 | 11.53 | 17.16 | 11.28 | 12.01 | 6.11 | 20.04 | 19.01 | 16.41 | 15.14 | 13.89 | 12.92 |
| Central Plateau | (30.22) | (12.91) | (12.3) | (21) | (19.3) | (15.47) | (6.12) | (15.04) | (13.48) | (12.05) | (11.07) | (10.31) | (9.83) |
| Gisborne | 41.18 | 23.51 | 32.93 | 15.80 | 25.85 | 38.46 | 33.70 | 28.50 | 30.17 | 26.52 | 26.32 | 26.96 | 27.87 |
| | (43.44) | (30.46) | (46.46) | (26.1) | (37.74) | (38.44) | (48.03) | (14.44) | (10.49) | (10.51) | (12.22) | (11.48) | (11.45) |

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Hawke's Bay | 45.32 | 27.81 | 38.49 | 36.59 | 28.42 | 31.71 | 31.03 | 33.81 | 37.68 | 35.28 | 33.83 | 32.38 | 31.74 |
| | (51.46) | (32.96) | (47.58) | (46.13) | (39.28) | (39.48) | (39.98) | (16.99) | (12.42) | (11.18) | (12.59) | (12.05) | (11.19) |
| Taranaki | 20.38 | 16.77 | 9.97 | 18.17 | 12.36 | 5.24 | 16.61 | 16.90 | 16.84 | 16.94 | 16.20 | 14.75 | 14.26 |
| | (30.25) | (16.21) | (13.4) | (20.94) | (24.32) | (7.15) | (15.39) | (10.73) | (9.48) | (10.58) | (9.45) | (9.11) | (8.73) |
| Manawatu / | 45.21 | 34.38 | 27.35 | 27.81 | 23.65 | 23.95 | 30.20 | 30.17 | 30.61 | 29.38 | 28.66 | 26.56 | 26.22 |
| Wellington | (62) | (28.09) | (34.03) | (29.85) | (33.11) | (31.34) | (26.11) | (8.05) | (7.00) | (11.52) | (10.44) | (10.8) | (10.29) |
| Wairarapa | 46.71 | 27.33 | 31.92 | 20.13 | 19.05 | 30.63 | 31.98 | 30.79 | 33.13 | 29.67 | 28.08 | 26.64 | 26.18 |
| | (58.15) | (23.34) | (41.11) | (23.24) | (29.42) | (37.57) | (35.96) | (13.09) | (10.02) | (11.61) | (11.96) | (11.82) | (11.3) |
| Marlborough | 48.84 | 49.48 | 35.37 | 26.66 | 18.05 | 41.73 | 27.33 | 35.08 | 37.72 | 38.42 | 36.09 | 35.20 | 33.88 |
| | (58.14) | (39.88) | (35.65) | (26.13) | (26.91) | (41.77) | (22.69) | (8.48) | (6.62) | (11.05) | (11.61) | (10.8) | (10.71) |
| Tasman | 35.54 | 27.85 | 15.72 | 10.35 | 8.63 | 16.64 | 7.04 | 25.73 | 23.09 | 21.70 | 20.01 | 18.20 | 16.55 |
| | (50.41) | (26.41) | (21.3) | (15.35) | (18.21) | (18.8) | (8.16) | (3.97) | (4.52) | (8.4) | (9.15) | (9.15) | (9.55) |
| West Coast | 2.58 | 1.73 | 0.72 | 1.69 | 0.81 | 0.63 | 1.01 | 3.28 | 2.02 | 1.80 | 1.65 | 1.39 | 1.27 |
| | (3.79) | (3.11) | (1.76) | (3.14) | (1.65) | (1.03) | (1.56) | (4.76) | (3.46) | (2.88) | (2.55) | (2.34) | (2.16) |
| Central | 45.47 | 35.57 | 30.55 | 18.06 | 26.27 | 38.07 | 43.58 | 30.16 | 30.74 | 29.87 | 29.59 | 29.32 | 29.47 |
| Canterbury | (52.06) | (28.7) | (37.65) | (20.23) | (30.76) | (44.64) | (47.82) | (5.16) | (3.79) | (7.55) | (9.15) | (9.08) | (9.06) |

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| South | 38.58 | 39.67 | 17.20 | 17.76 | 28.02 | 29.59 | 45.97 | 27.19 | 28.40 | 28.16 | 28.24 | 27.98 | 28.14 |
| Canterbury | (47.76) | (35.09) | (16.67) | (23.07) | (32.23) | (31.39) | (39.65) | (10.42) | (8.95) | (9.2) | (9.58) | (9.33) | (9.46) |
| Otago | 32.67 | 37.74 | 16.30 | 14.62 | 30.58 | 30.71 | 33.16 | 25.56 | 27.13 | 26.69 | 26.62 | 25.11 | 24.30 |
| | (45.64) | (35.37) | (16.09) | (16.3) | (33.2) | (30.5) | (30.69) | (9.42) | (8.29) | (8.01) | (8.2) | (8.87) | (8.81) |
| Southland | 13.26 | 11.87 | 3.97 | 12.31 | 17.07 | 16.34 | 8.93 | 13.10 | 12.04 | 12.86 | 13.59 | 12.29 | 11.48 |
| | (24.65) | (17.69) | (4.76) | (14.43) | (20.31) | (20.04) | (10.43) | (3.64) | (5.31) | (4.63) | (5.57) | (6.09) | (5.89) |

Notes: Potential Evapotranspiration Deficit (PED) data from NIWA for 17 climate regions. PED is measured as mm of water needed to supplement current precipitation to maintain vegetation growth under no water scarcity. Average PED is calculated by climate region as the average of the January to June average PED for that given year. Long-run average PED is calculated by climate region as the average of the January to June average PED over the previous X years. The standard deviation is shown in parentheses.

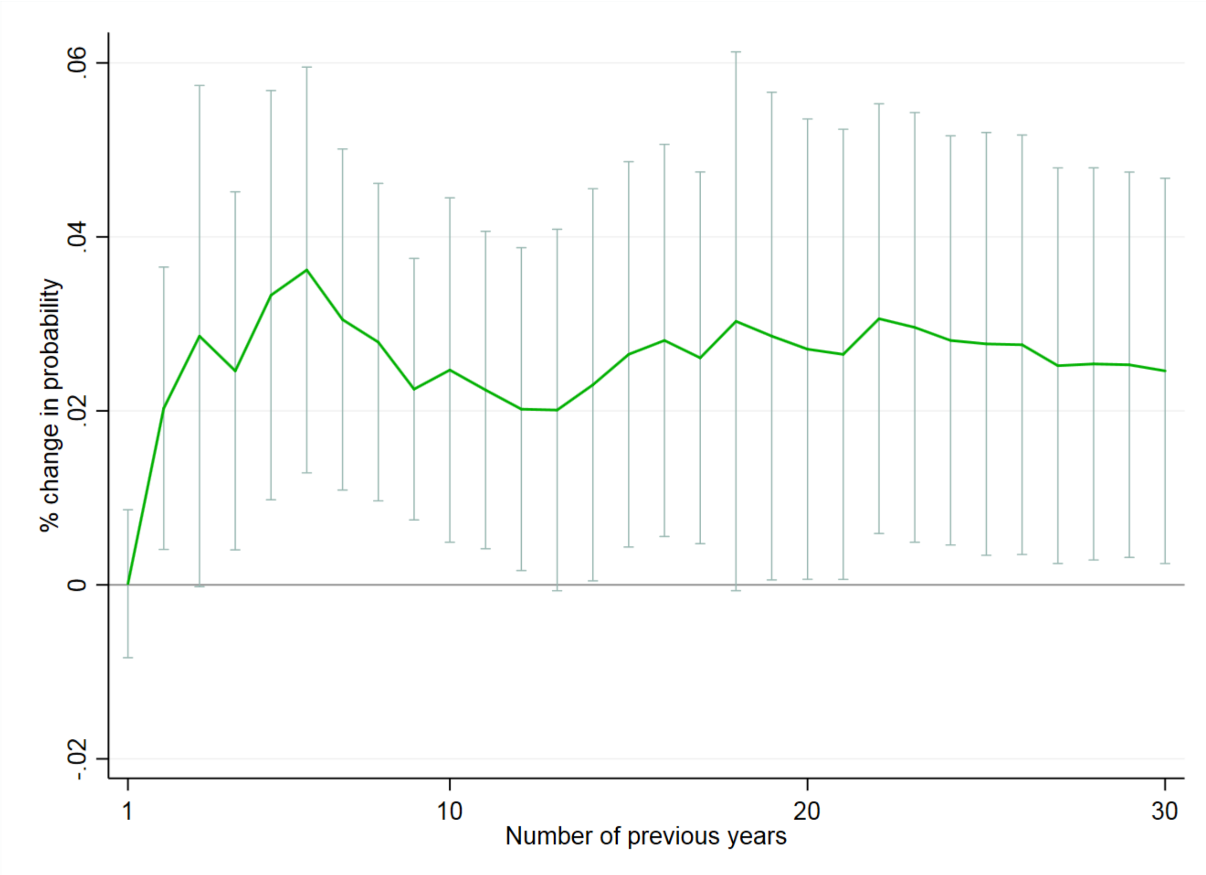


**Figure A1. Average marginal effects of deviations from 1 to 30-year long run average PED at the region level for average PED 6-months prior to survey**

Notes: This figure shows the average marginal effects and 95% confidence intervals for the percent change in average 2015 PED from the long-run average PED using PED from the 6 months before respondents taking the survey. This is estimated in a multi-variate logit regression of the expectation of future drought prevalence by 2050. Data are from NIWA and the Survey of Rural Decision Makers 2015. These models used 561 observations.