

# Impact of projected mid-century temperatures on common southwestern specialty and field crops (H43J-1104)

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## Abstract

The impacts of increased temperatures in agricultural ecosystems are complex, varying by region, cropping system, crop growth stage and humidity. We analyze the impacts of midcentury temperature increases on common southwestern crops to produce a spatial impact assessment of select specialty (grapes, almonds and tomatoes) and field (alfalfa, cotton and corn) crops. This analysis includes three main components: development of normal temperature envelopes for each crop, classification of predicted future climate conditions according to these envelopess, and mapping the probable impacts of these climatic changes on each crop. We use 30m spatial resolution 2012 crop distribution and seasonal minimum and maximum temperature normals (1970 to 2000) to define the current thermal envelopes for each crop. These represent the temperature range where 95% of each crop is presently grown. We estimate future temperatures using seasonal midcentury temperatures downscaled from 20 coupled model intercomparison project (CMIP5) models (RCP8.5). Change detection maps represent areas predicted to become more or less suitable, or remain unchanged. Based upon mid-century temperature changes, total regional suitable area declined for all specialty crops, but nearly doubled for cotton and increased slightly for alfalfa (2%). For each crop there are locations which change to and from optimal temperature envelope conditions. More than 80% of the acres currently growing tomatoes and almonds will shift outside the present 95% temperature range. Over half the area growing grapes will shift outside the present 95% summer maximum temperature range. Fewer acres currently growing alfalfa (14%), cotton (6%) and corn (12%) will shift outside the present 95% thermal range by midcentury. Crops outside present thermal envelopes by midcentury may be aided to adapt to the new temperature regime or growers may elect to grow alternate crops better suited to future thermal envelopes.

## Introduction

Spatial vulnerability assessments are useful tools for understanding patterns of risk and vulnerability to climate change. The common paradigm for assessing vulnerability includes estimates of exposure, sensitivity and adaptive capacity. Here we develop a novel method to evaluate expected midcentury exposure based upon thermal regimes of current crop location. This analysis describes how much of the 2012 crop area will be outside the current temperature 95% confidence interval by 2040-2069.

## Methods

This crop impact assessment had three main components: I. development normal temperature envelopes (TE) for each crop, II. classification of predicted future climate conditions according to these thresholds, and III. mapping the probable impacts of climatic changes on each crop. We evaluate three specialty crops and three field crops, selected based on regional importance and classification accuracy.

Table 1. Normal temperature envelope for select specialty and field crops based on crop location and PRISM data.

Crop	Season	Median	Temperature in degrees C				% 97.50%	Range
			Minimu	Maximu	2.50	m		
Almonds	Winter	3.4	-5.9	10.2	2.9	3.9	0.9	
Alfalfa	Summer	32.7	11.4	45.0	26.5	41.5	15.0	
Corn	Summer	33.6	14.0	45.0	29.5	40.7	11.2	
Cotton	Summer	35.2	14.7	45.0	32.5	41.5	9.0	
Grapes	Summer	33.7	15.6	45.0	24.2	36.1	11.9	
Tomatoes	Summer	33.7	17.8	41.4	29.6	35.7	6.1	

### I. Normal temperature envelope

By combining current crop distributions with seasonal 30-year temperature normals, we identified the 95% range of seasonal temperatures by crop location (normal TE; Table 1). We calculated normal TE for each crop using 2012 landcover classifications (USDA CropScape) and thirty-year temperature normals (1970 to 2000; PRISM modeling group). CropScape data were acquired on a state-by-state basis and mosaicked in Arcmap 10.2. PRISM data were obtained for the continental United States, clipped to the southwest region, and resampled to a 30m pixel size to match CropScape data. The spatial extent of each crop was extracted from the temperature data for each season. We calculated the 2.5 and 97.5 percentile to obtain the temperature range where 95% of each crop was grown and an estimate of the current climatic conditions.

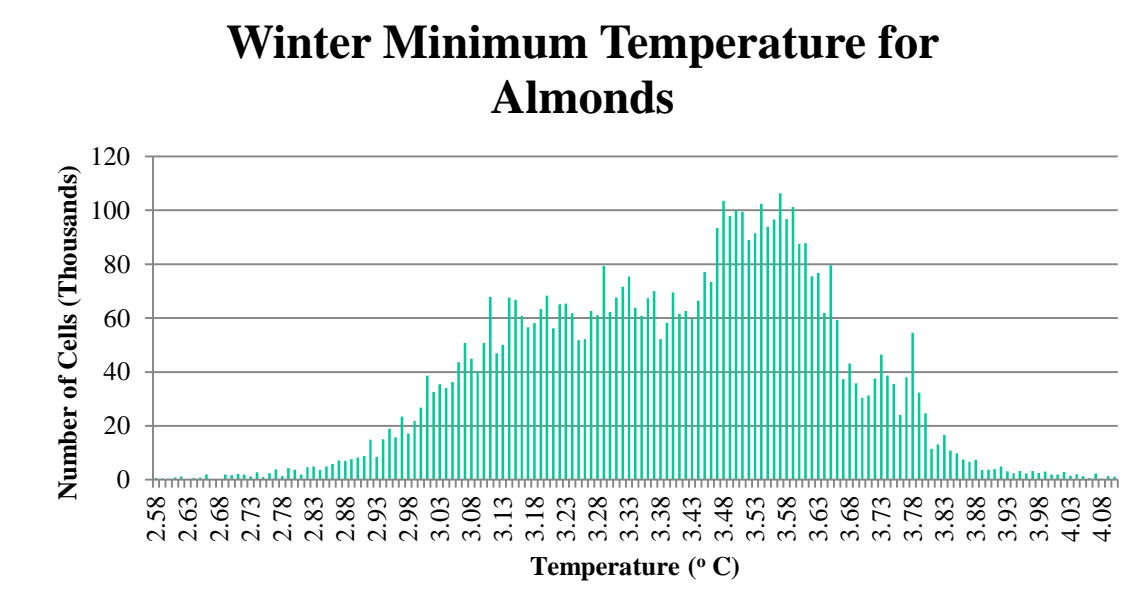
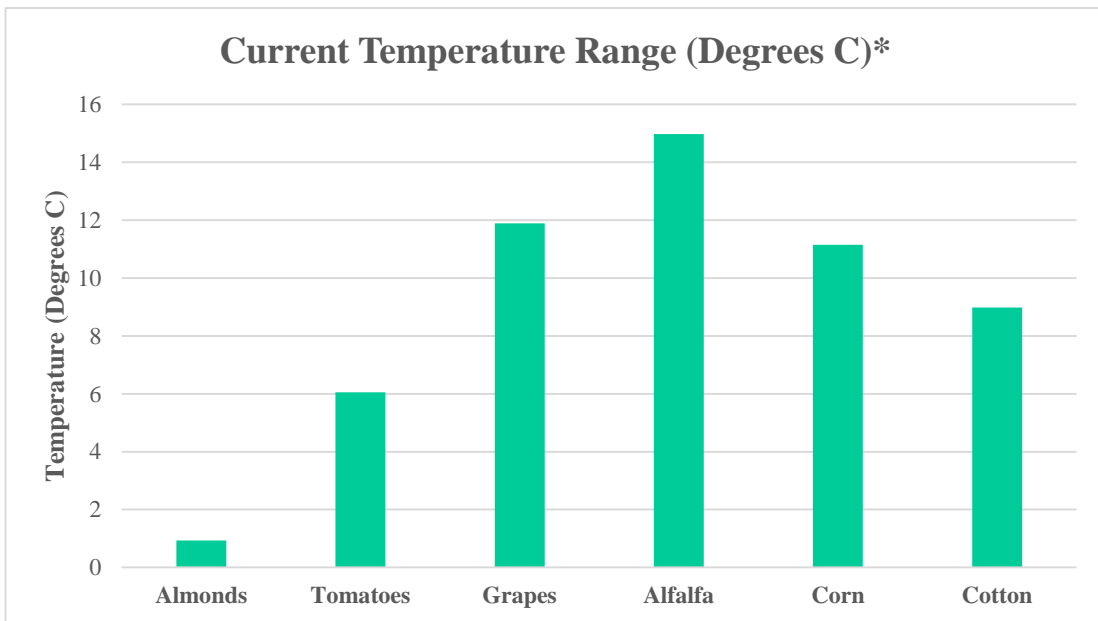


Figure 1: Histogram of Almond Climatic Conditions



\*Temperature range for winter minimum for almonds. All other crops are for summer maximum

Figure 2: Range of current climatic conditions for specialty crops.

### II. Mid-century temperatures

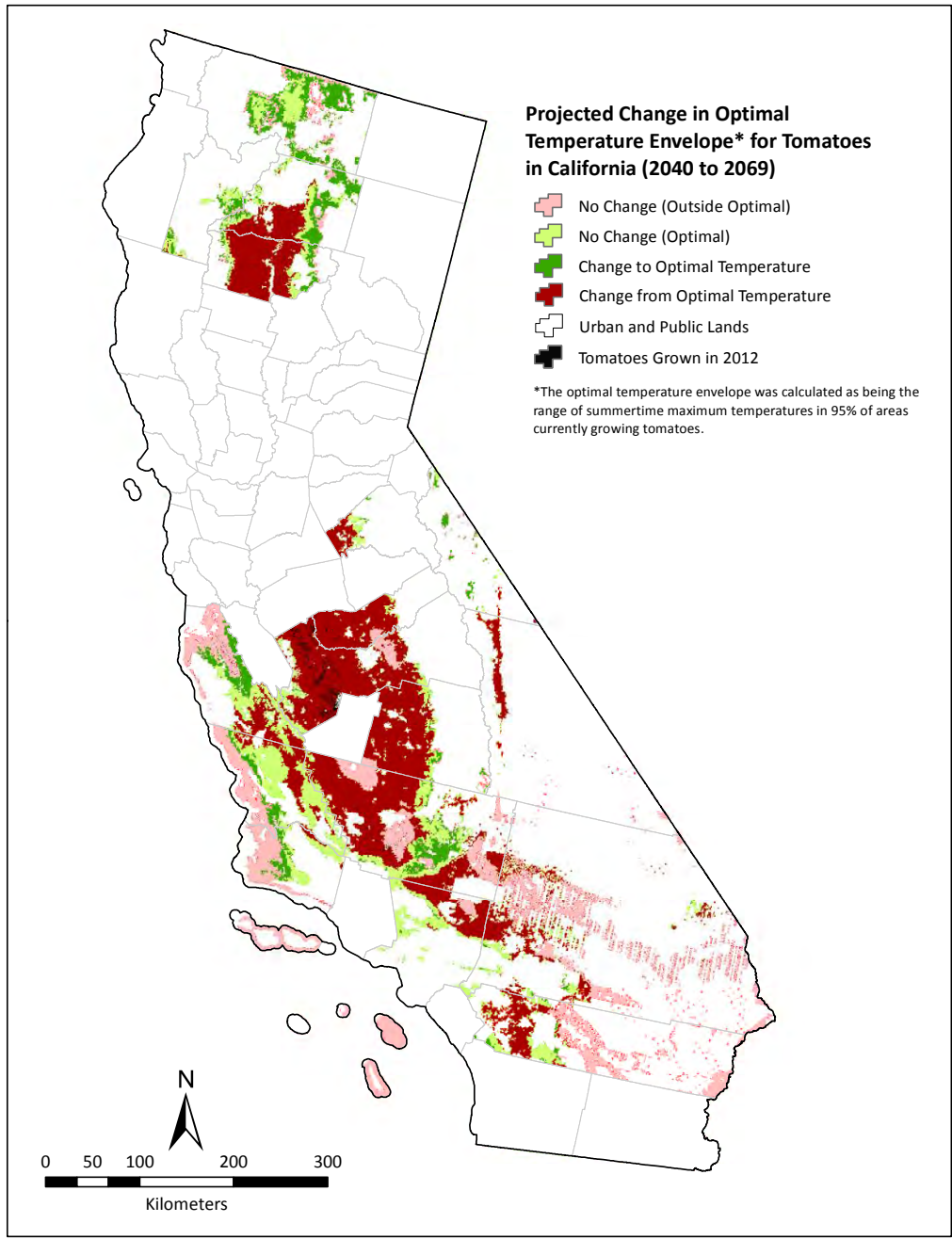
We classified the southwestern landscape into areas by crop using the multivariate adaptive constructed analogs (MACA) statistically downscaled data of the CMIP5 20-model midcentury (2040-2069) temperature mean. Since MACA data are the projected change in temperature, we summed MACA and PRISM data to produce absolute projected temperatures. We removed public lands, urban areas, and water bodies as they are unlikely to become future agriculture.

### III. Mapping temperature changes

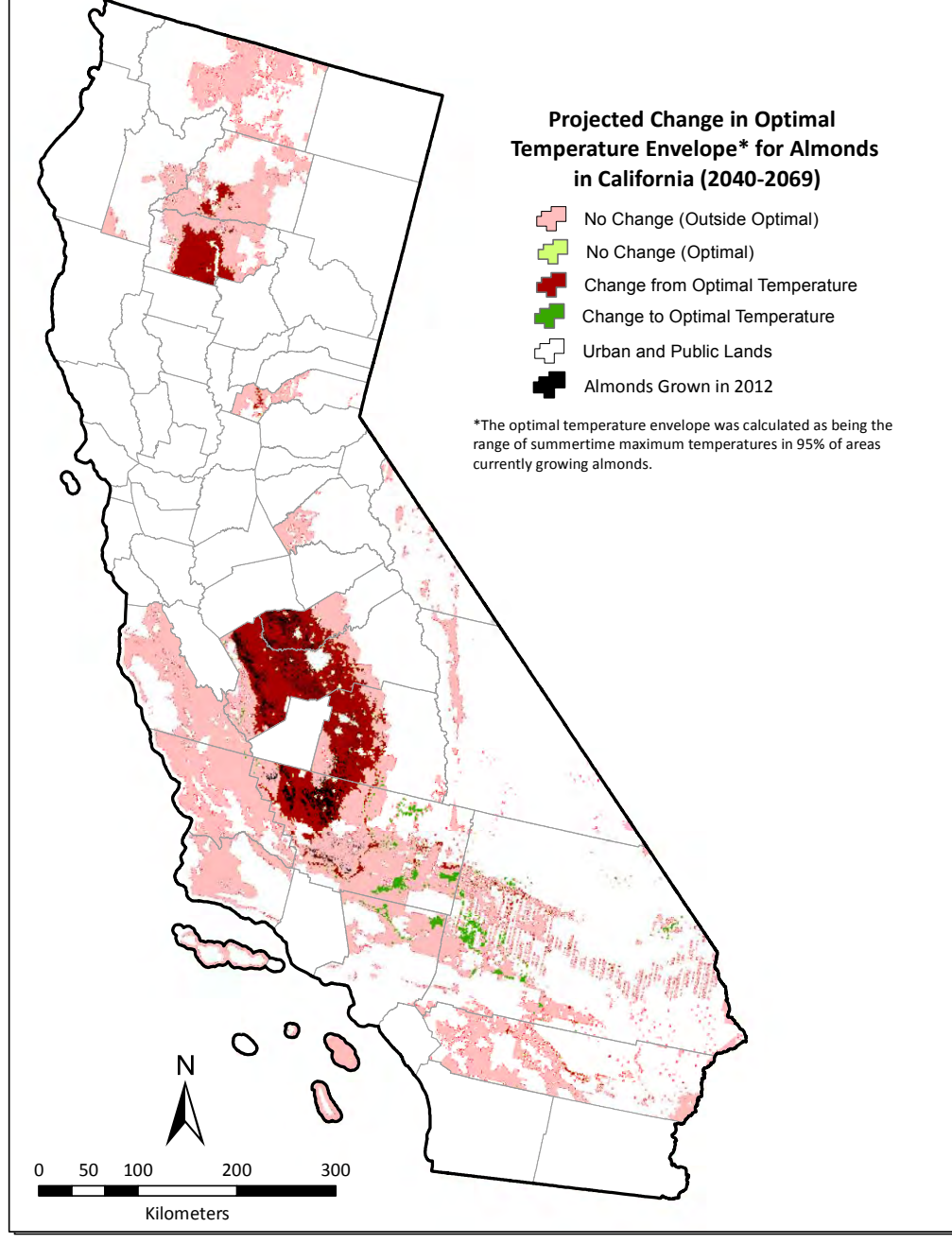
We selected one season for each crop, based on estimated vulnerability, to define temperature rules in a decision-tree classification in ENVI 5.2. After developing decision trees for each crop, we applied the trees to both the MACA and PRISM datasets to produce change detection maps showing areas predicted to shift outside the normal TE where 95% of the crop is presently grow, change to temperatures of the normal TE or stay the same.

## Results

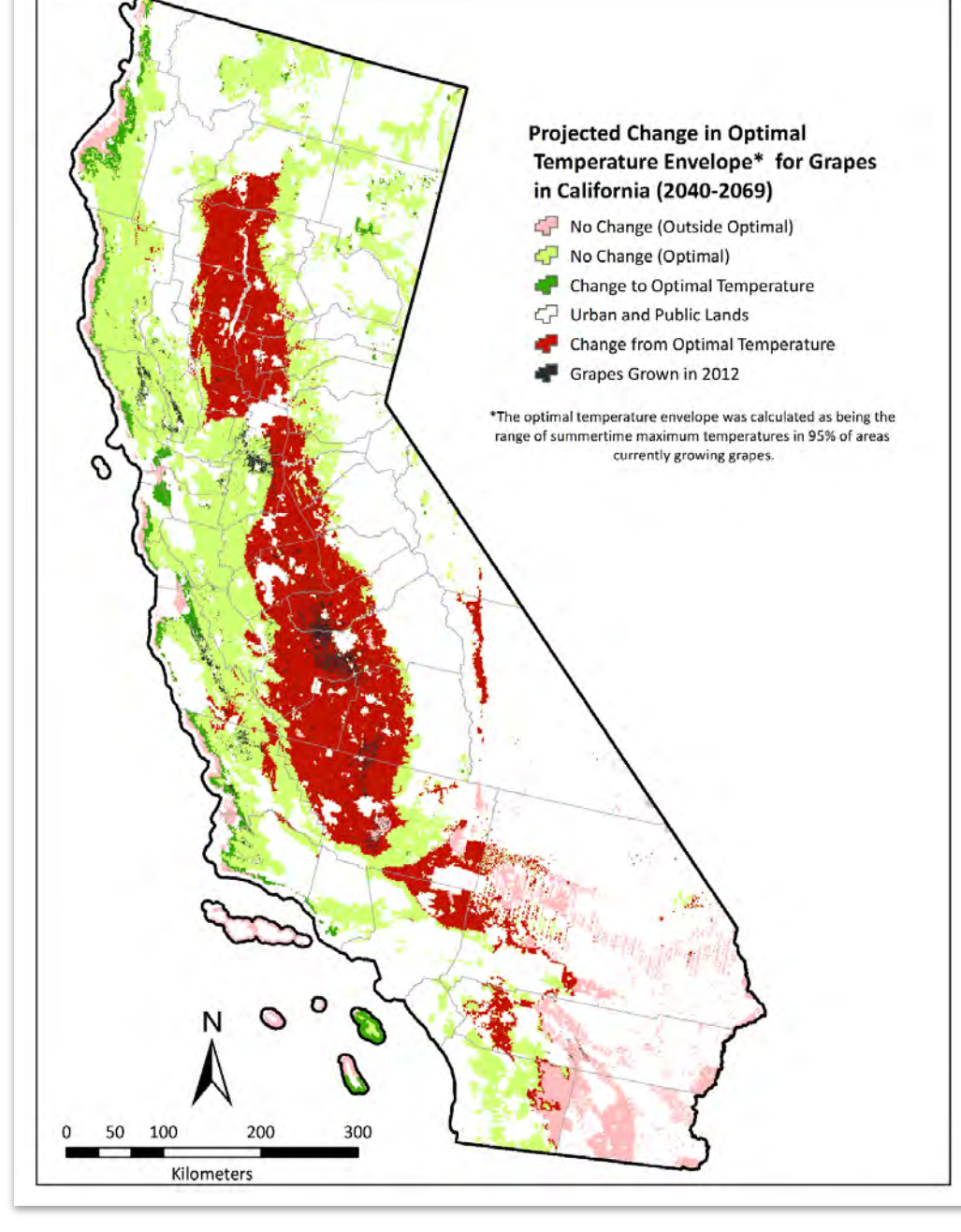
Only almonds were evaluated using winter temperatures because of chilling hour requirements. The winter mean temperature ranges from 2.9 to 3.9 °C for 95% of the almond crop (0.9 °C range). Summer normal TEs were used for all other crops. Alfalfa was grown on the largest range of mean summer temperatures (26.5 to 41.5 °C; 15 °C range) whereas tomatoes were grown on the smallest range (6.1 °C), likely because of their limited geographic distribution. Grapes and corn had a similar range (11.2 and 11.9 °C, respectively), however the TE was ~5 °C warmer for corn than grapes. Based upon temperatures of current crop distribution, the future area in CA with a similar temperature range will decrease for tomatoes (-38%), grapes (-39%) and almonds (-97%). Crops may withstand the new temperatures, but sensitivity must be evaluated on a crop by crop basis. For SW field crops, based upon the normal TE, area suitable to grow cotton will nearly double (57 M acres to 108 M acres) and alfalfa will increase slightly (2%), however the TE where corn could be grown will decrease by 22 M acres (20%) by midcentury.



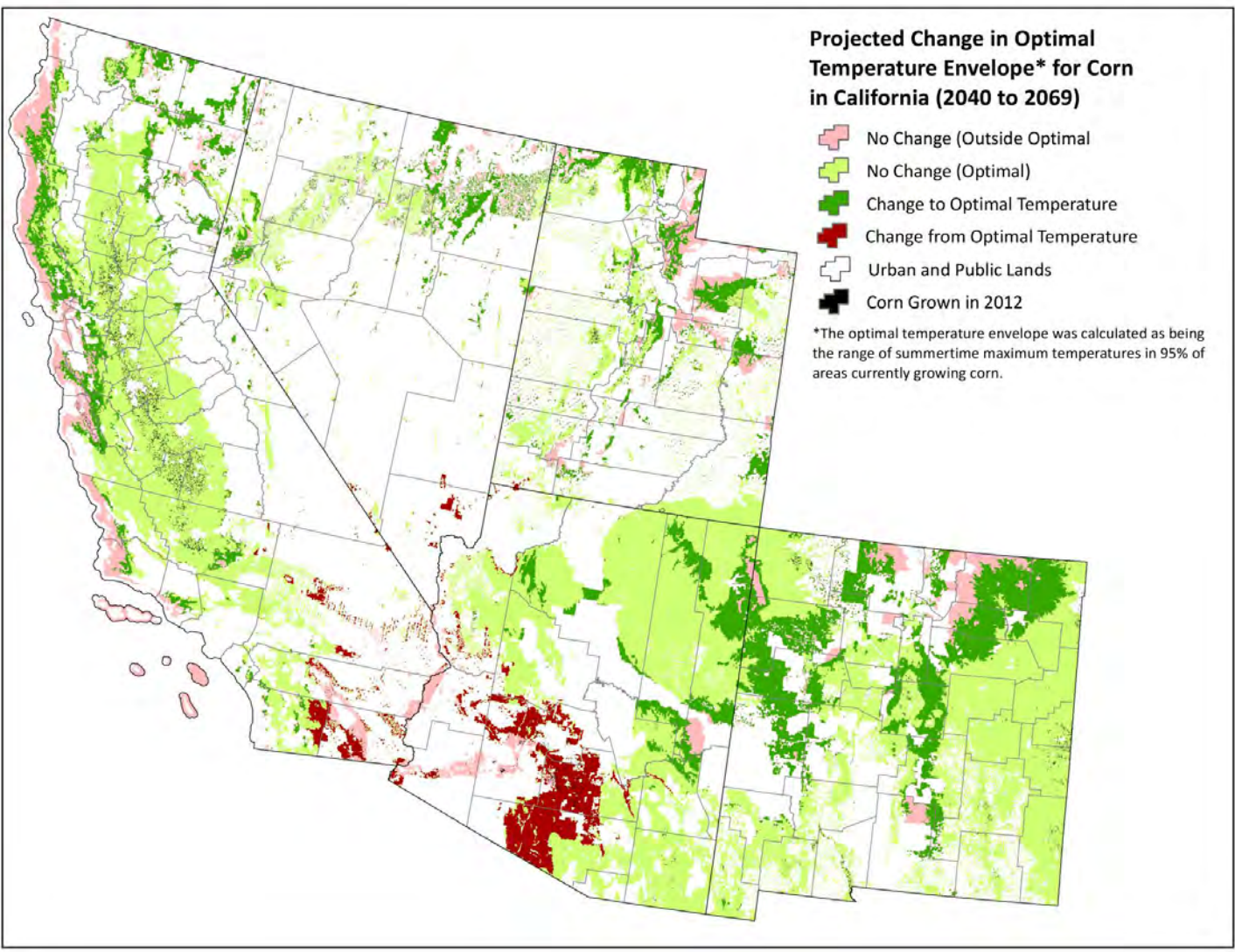
CA tomatoes are primarily grown within the Central Valley. Of the 340,000 acres of tomatoes grown in CA in 2012, over 280,000 acres (83%) shifted outside the summer normal TE (29.6 to 35.7 °C). Several regions remain within the normal TE by midcentury, including the western portions of San Joaquin, Sacramento, and Stanislaus Counties. Based upon summer maximum temperatures, 26.2 M acres in CA currently fall within the 95% normal TE. By midcentury, this number will drop by 10 M acres (-38%), indicating that ~ 16 M acres in 2040-2069 will fall within the current temperature regime of tomato cultivation.



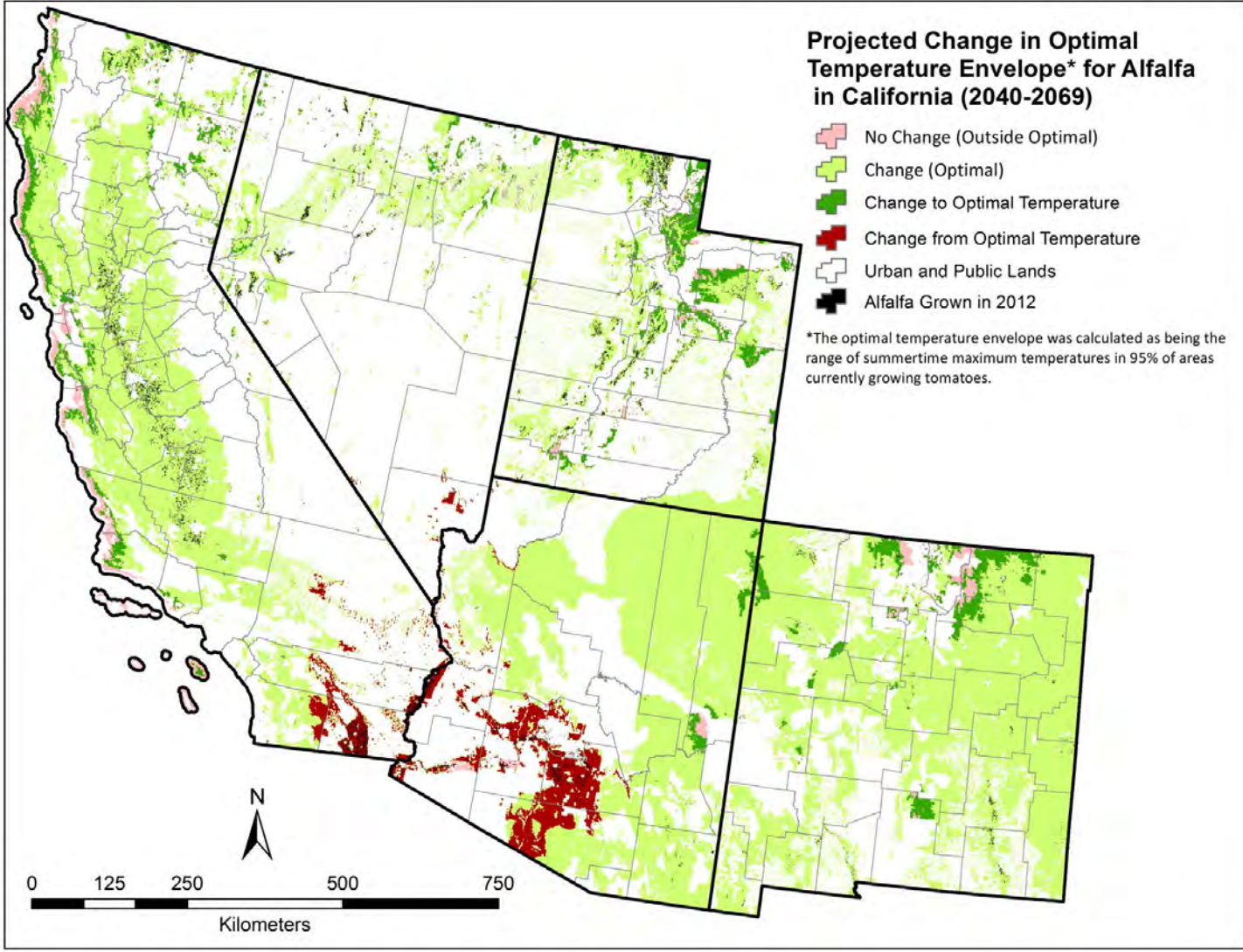
Almonds are presently grown on 1.2 M acres and 14.9 M acres in CA fall within the potential TE. The future area within the normal thermal envelope will be less than 0.5 M acres by 2040-2069. Nearly all of the Central Valley's TE of winter lows transitioned outside of the present TE. Of the 1.2 M acres designated as almonds, 94% or 1.1 M acres were impacted. These areas were projected to have winter minimums that exceeded the current winter minimum thermal envelope. How this warming winter temperature will affect winter chilling requirements should be evaluated.



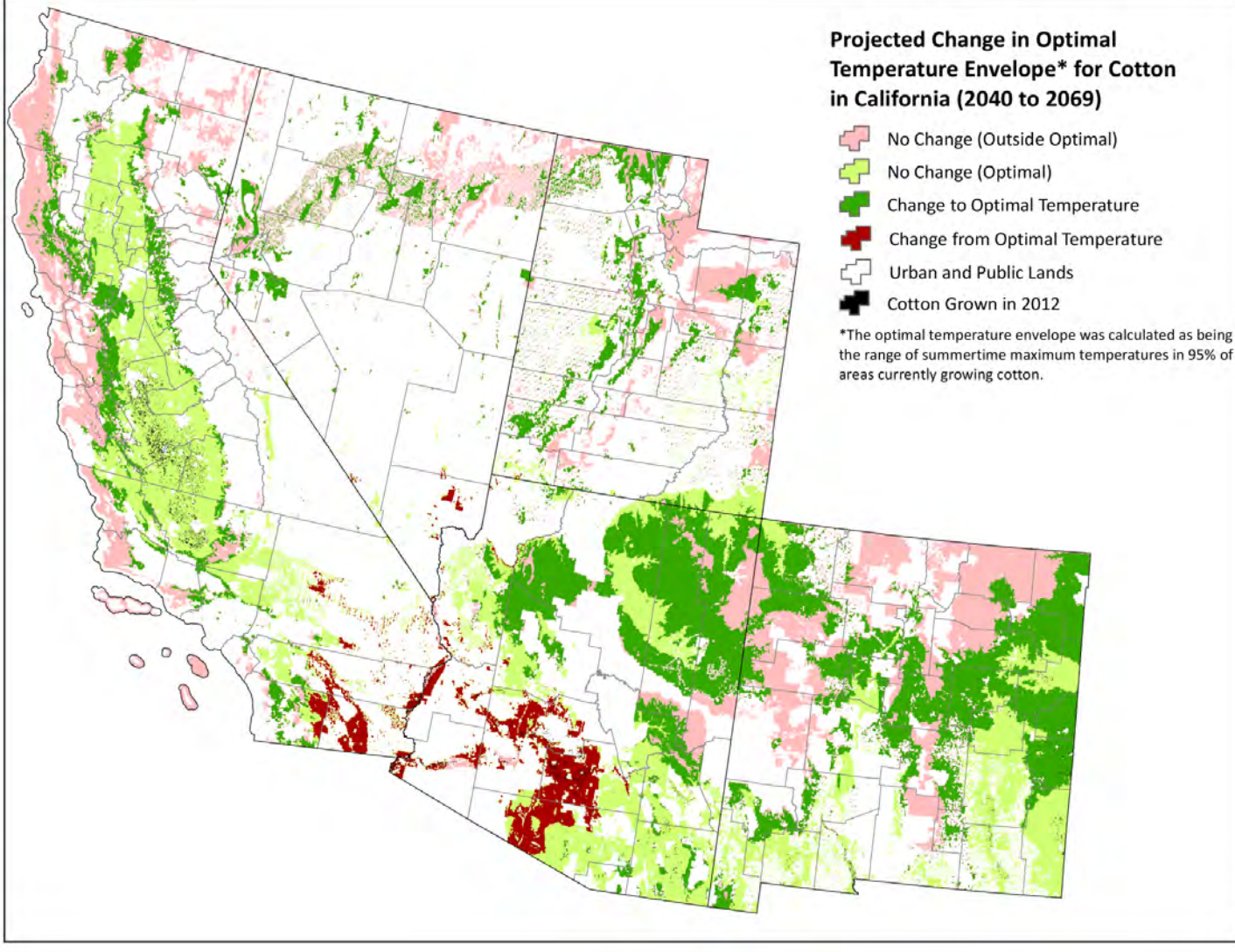
Of the 917,000 acres growing grapes in 2012, 52% had temperatures moving outside the present TE, mostly within the Central Valley. Of the 37.3 M acres suitable for grape growing in CA, 15.7 M left the normal TE by midcentury. Nearly 1.5 M of the 6.3 M current non-optimal acres were projected to move into a suitable thermal envelope for grape growing, typically bordering well-known grape growing regions. The lower coastal impact was a function of the lower projected summer warming along the CA Coast.



In 2012, corn was grown on 620,000 acres. By midcentury 74,000 acres (12%) will shift outside the normal summer TE of 29.5 to 40.7 °C. The area within the potential TE decreases from 107.3 M acres to 85.3 M acres by midcentury. The temperature for reproductive failure for corn is ~35 °C. Changes in the areal extent above 35 °C will be evaluated in the future.



The normal TE for alfalfa was 26.5 to 41.5 °C. Alfalfa was grown on 2.7M acres across the SW in 2012. By midcentury, the area within the 95% normal temperature range decreased by 14%. The areas of alfalfa cultivation that were impacted by the changing temperature regimes were the Imperial Valley in California, the lower Colorado River Valley along the California/Arizona border, and the Gila River corridor west of Phoenix. Across the region, the area within the normal temperature range will increase by 2% or 3M acres by midcentury. However, alfalfa grown in hot temperatures can have significantly reduced yield. Evaluation of new temperatures in relation to yield should be conducted.



Cotton is currently grown in the warmest areas of the SW. Of the 660,000 acres grown, 6% short outside the normal TE for cotton (32.5 to 41.5° C). Due to the projected increases in midcentury temperatures, the TE for cotton nearly doubles by midcentury. The figure above portrays a northward expansion of potential land for growing cotton. Only 7M acres, all within California, Arizona, and southern Nevada, are projected to transition from the optimal TE.

## Conclusions

- A large proportion of specialty crops will experience an entirely new thermal regime by midcentury.
- 94% of almond acreage will shift outside winter normal temperature envelope and future locations and chilling hours should be evaluated.
- 83% of tomatoes and 52% of grapes acres shift outside normal summer temperature envelope by midcentury.
- Fewer field crops shift outside normal temperature envelope: alfalfa (14%), cotton (6%), and corn (12%).
- Across the region, future suitable area decreases for tomatoes, grapes, almonds, and corn but increases for cotton and alfalfa.
- Impacts of future temperatures should be evaluated on a crop by crop basis.

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