Appendix C: Characterizing Crop Production Regions and Regional Crop Yield Modeling

Each crop production region is divided into production on highly erodible land (HEL) and non-highly-erodible land (NHEL), and each land type (HEL or NHEL) is represented by one or more soil series, depending on the amount of cropland in that region and land type. Regions with less than 1 million acres of cropland in a land type are generally represented by a single soil for that land type. An additional soil type is brought in for (roughly) every additional million acres of cropland on a specific land type (HEL or NHEL). Production in each region is represented by a set of production enterprises that capture the rotations and field production methods used to produce crops in that region. Each production enterprise is simulated across all the soils selected to represent a given region; soil-specific yields and environmental impacts estimated at the field scale are then averaged, using acreage weighting based on soil extent within that region, and those average yields and environmental impact measures are used as representative regional results (i.e., yield and environmental impact measures) for that production enterprise.

Soil properties for each region and soil type are calculated using an overlay of the NASS (USDA's national Agricultural Statistics Service) cropland data layer and the SSURGO database (USDA NASS CDL 2012, SSURGO 2013). The cropland data layer identifies cropland within each REAP (Regional Environment and Agriculture Programming model) region, and the SSURGO database is used to divide that regional acreage into highly erodible (HEL) and non-highly-erodible (NHEL) map units and to characterize the soil types underlying those map units and the crops within them. Soil series chosen to represent each region are based on a consideration of soil coverage as well as importance for predominant crops within the region. Soil properties for each region are calculated by area weighting the individual soil properties by soil map unit (SMU), soil series name (aspatial), Cropland Data Layer (CDL) crop class, and erodibility status (HEL or NHEL) for each REAP region to estimate representative soil properties by region. This exercise is done for the selected set of soil series described above. The weights are calculated as the area in each REAP region in each unique combination of SMU, crop class, and erodibility status multiplied by the SMU representative component percent of each soil series. A second set of weights is calculated for those properties that are described throughout the various horizons of the soil profile as the SMU average representative horizon width. Properties described at the soil map unit level, and not described in the horizons, are weighed by the first weight only, and properties described in the soil horizons are multiplied by both weights. The weighted soil properties are finally aggregated to each of the soil series in each REAP region.

EPIC Crop-Growth Modeling

Projected crop-yield response to temperature change in a region depends on where the new temperature conditions fall relative to the range of optimal growing conditions for specific crops. EPIC users may specify both the minimal temperature and optimal temperature for crop growth; growth rate declines on either side of the optimal temperature. Estimates of crop-yield response to climate change are therefore highly sensitive to the specification of crop-specific temperature thresholds. The crop-specific critical temperature thresholds used in this analysis are shown in appendix table 2. While the development of heat-tolerant crops may result in altered ranges of optimal growing conditions in the longer term, this analysis assumes that these critical thresholds remain constant across all analysis periods.

Appendix table 2: Optimal and minimum temperatures for growth for REAP crops

Name	Optimal temperature (^oC)	Minimum temperature (^oC)
Soybeans	25	10
Corn	25	8
Grain sorghum	27.5	10
Cotton	27.5	10
Winter wheat	15	0
Spring wheat	15	0
Barley	15	0
Oats	13	2
Rice	25	10
Corn silage	25	8
Sorghum hay	27.5	10
Hay - Alfalfa	15	1
Hay - Timothy	25	8

Note: REAP = Regional Environment and Agriculture Programming model.

Changes in carbon dioxide are also entered into EPIC in accordance with expected CO_2 concentrations for each emissions scenario for each time period (Appendix table 3).

Appendix table 3: Atmospheric CO_2 concentration used for each SRES emissions scenario (ppm).

SRES scenario	Reference	2020	2040	2060	2080
B2 (_Low)	381	408	453	504	559
A1B (_Mid)	381	420	491	572	649
A2 (_High)	381	417	490	580	698

Note: SRES = Special Report on Emissions Scenarios.

Changes in carbon dioxide concentration are expected to affect crop yields through two different pathways—first, through its impact on the efficiency of the photosynthetic pathway (radiation-use efficiency) and second, through its impact on the efficiency of crop respiration, or transpiration. Crops have two different metabolic pathways for photosynthesis, labeled C_3 and C_4. Of the major field crops included in the REAP model, only corn and sorghum are C_4 crops. CO_2's impact on transpiration, which depends to a large extent on crop water stress and soil moisture levels, can operate in both C_3 and C_4 crops; the photosynthesis effect, on the other hand, is generally thought to affect only C_3 crops such as wheat, soybeans, and cotton (Walthall et al., 2012). C_3 crops are therefore projected to have a higher yield response to carbon fertilization than C_4 crops.

There is considerable uncertainty in the literature surrounding potential carbon dioxide fertilization impacts on crop yields under realistic field growing conditions. Based on an extensive review of research, the USCCSP (2008) reports estimated percent changes in yield due to a doubling of CO_2 ranging from 4 percent in corn, 0-8 percent in sorghum, 44 percent in cotton, and 34-38 percent in soybeans. Actual responses to carbon enrichment will depend upon the extent to which crop growth is constrained by other stressors such as nitrogen or water limitations (Walthall et al., 2012).

EPIC allows CO_2 to affect plant growth through both pathways. The first pathway accounts for carbon dioxide's impact on plant photosynthesis by adjusting the crop's radiation-use efficiency as carbon dioxide concentrations change, based on crop-specific CO_2 response parameters. To represent the relationship between CO_2 and radiation-use efficiency (represented in EPIC by the "biomass energy ratio"), EPIC fits an s-curve to two points describing radiation-use efficiency at different CO_2 concentrations. The radiation-use efficiency change attributable to carbon dioxide is as shown in appendix table 4. Carbon dioxide is assumed to have a less significant impact on the radiation-use efficiency of REAP's C_4 plants—corn, corn silage, sorghum, and sorghum hay.

When the Penman-Monteith evapotranspiration (ET) estimation method is used, EPIC also reduces ET demand as carbon dioxide concentrations increase, making plants more water-use efficient and drought tolerant in response to increased ambient carbon dioxide. In order to capture the important potential effects of carbon dioxide concentration on water-use efficiency, we used the Penman-Monteith ET estimation method in our crop yield modeling.

Appendix table 4: Impact of CO_2 concentration on biomass energy ratio for each REAP crop

Name	CO_2 concentration (ppm)	Biomass energy ratio
Soybeans	330	17
	700	20
Corn	330	35
	700	37
Sorghum	330	30
	700	32
Cotton	330	15
	700	18
Winter wheat	330	25
	700	30
Spring wheat	330	25
	700	30
Barley	330	20
	700	24
Oats	330	20
	700	24
Rice	330	35
	700	42
Corn silage	330	35
	700	37
Sorghum hay	330	30
	700	32
Hay	330	20
	700	24

Note: REAP = Regional Environment and Agriculture Programming model.

Changes in crop yields resulting from future climate conditions in the EPIC simulations are directly attributable to differences in average temperature, precipitation, and atmospheric carbon dioxide concentration. They are also indirectly attributable to changes in soil conditions arising from farm production enterprises and practices under the altered climate condition. To capture the effect of a range of different weather patterns on yield, each regional rotation for a given soil is run through EPIC five times under five different random weather regimes. Each EPIC run is modeled over 30 years; estimates of yield and observed environmental indicators for the first 20 years are discarded to allow soil conditions to settle from their initial values. Each EPIC run thus results in 10 years of yield estimates with changed weather conditions each year. Because each run is replicated five times, final average yield and environmental impact estimates are calculated by rotation based on the EPIC estimates for 50 years of simulated weather conditions for each crop.

Because estimates of the variability of future weather cannot be derived from either the original or the downscaled GCM climate data, the variability of weather and therefore the relative incidence of extreme weather events are held constant in this analysis between the reference and future weather scenarios. Average climate conditions shift, however, so the conditions associated with an extreme event (temperatures and precipitation occurring at a specific deviation from the average) shift as well in our analysis.

Sensitivity of Crop Yields to Climate Change Elements

EPIC's calculation of the yield impacts of simultaneously changing values of temperature, precipitation, and carbon concentration drives REAP's analysis of the impacts of future climate change projections relative to a reference climate case. EPIC's results are in turn driven by a large set of technical parameter assumptions that are held constant across climate projections. These parameters influence the relative impact of temperature, precipitation, and carbon fertilization on crop yields, and can subsequently influence differences in impact across future climate projections. Examples of such assumptions include the minimal and optimal growth temperatures for each crop, the parameters of the relationship between carbon fertilization and crop growth, and water-related parameters such as maximum stomatal conductance and assumptions about the rate of decline in radiation-use efficiency with increasing vapor pressure deficits.[1]

Because there is ongoing debate about the expected magnitude of dynamics such as carbon fertilization, and to understand how each element of the climate change impact behaves individually in EPIC's results, it's helpful to present disaggregated climate change impact results for each of the climate elements that vary. This section presents results for scenarios in which temperature, precipitation, and carbon concentration are varied independently of one another in the combinations shown in Appendix table 5. Note that due to interaction effects, the impacts of the combined changes are not a strict sum of the impacts of the individual effects. The impact of temperature on evapotranspiration rates, for example, can alter the sensitivity of precipitation impact results to temperature changes. The sensitivity analysis is presented for crop yields calculated in 2060 varying the elements of the CSIRO_Mid projections.

Appendix table 5: Scenarios used for exploring sensitivity of yield impacts to climate change elements

	Reference	All	Just CO_2	Just precip.	Just temp.
Temperature	Reference	CSIRO_Mid_2060	Reference	Reference	CSIRO_Mid_2060
Precipitation	Reference	CSIRO_Mid_2060	Reference	CSIRO_Mid_2060	Reference
CO_2 concentration	385	572	572	385	385

To isolate the biophysical impacts from the behavioral impacts in this analysis, production acreage by region, crop, and cropping system is held fixed across all the scenarios; the only elements varying are the per-acre yield calculations generated by EPIC for the given combination of climate element adjustments. The changes in productivity illustrated are therefore due exclusively to the changes in biophysical impact simulated by EPIC. Regional changes in productivity reflect changes in productivity at the rotation level that are then weighted by rotation acreage and aggregated up to the regional level. Regional rotations are listed in Appendix D.

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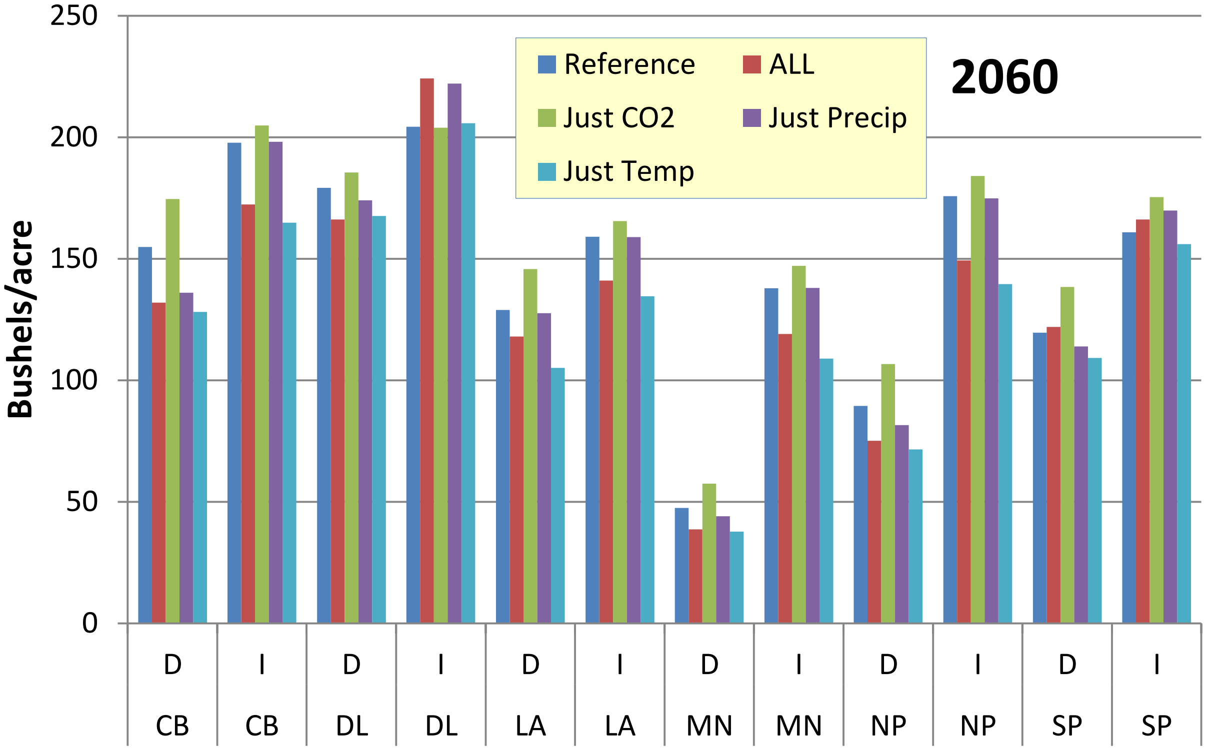
[1] For a complete list of EPIC's parameters, see the EPIC documentation at http://epicapex.tamu.edu/files/2015/10/EPIC.0810-User-Manual-Sept-15.pdf

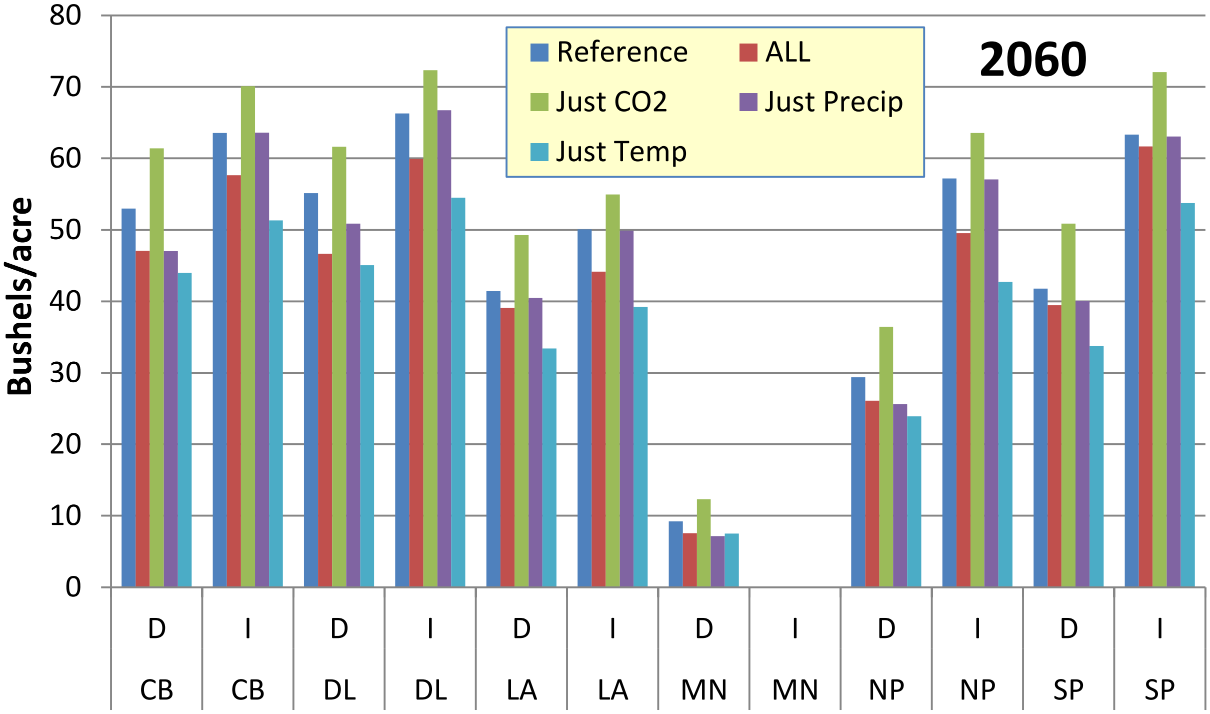
Impacts on yields of corn, soybean, and wheat for select regions are shown in 20-22 for the scenarios described above. Note that these yields, which directly reflect EPIC output, have not yet been calibrated by REAP to meet either current observed yields or expectations of technological change, and are therefore generally lower than the yields used in the economic analysis for the year 2060.

Appendix figure 20: Impacts of climate change on corn yields of individual elements for the CSIRO_Mid projection in 2060



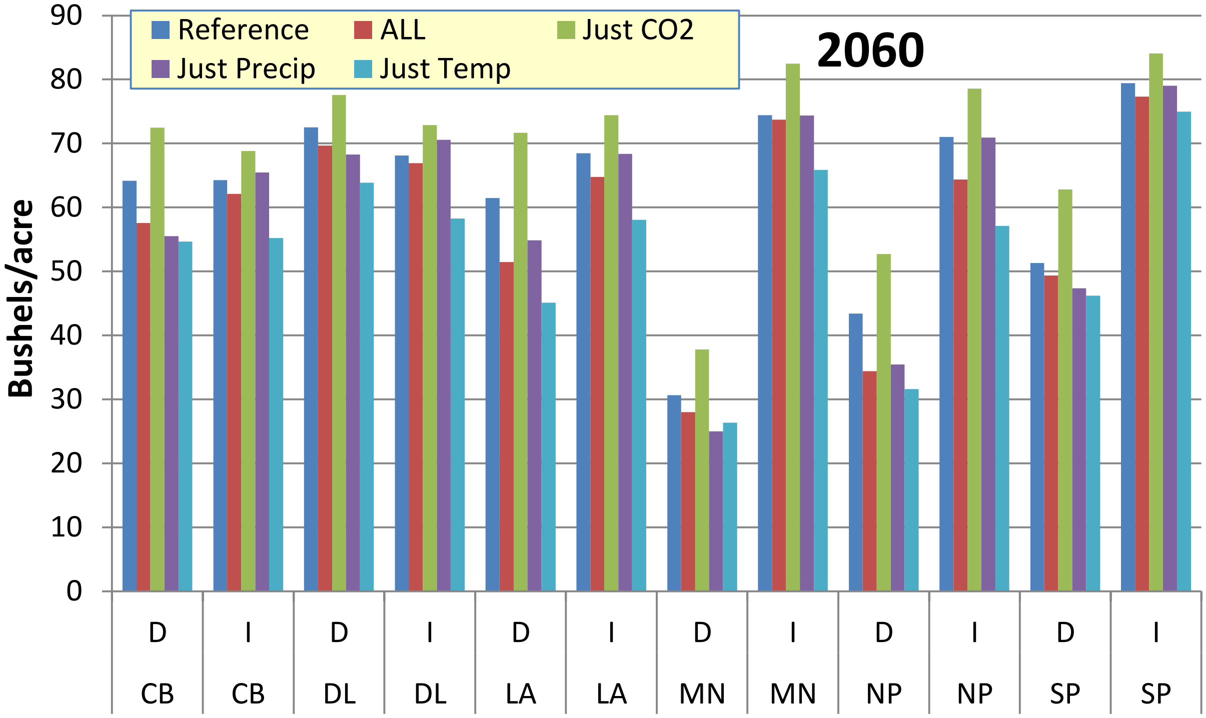
D = dryland; I = irrigated. AP = Appalachia, CB = Corn Belt, DL = Delta States, LA = Lake States, MN = Mountain States, NE = Northeast, NP = Northern Plains, PA = Pacific, SE = Southeast, and SP = Southern Plains.

Appendix figure 21: Impacts on soybean yields of individual elements of climate change for the CSIRO_Mid projection in 2060.



D = dryland; I = irrigated. AP = Appalachia, CB = Corn Belt, DL = Delta States, LA = Lake States, MN = Mountain States, NE = Northeast, NP = Northern Plains, PA = Pacific, SE = Southeast, and SP = Southern Plains.

Appendix figure 22: Impacts on wheat yields of individual elements of climate change for the CSIRO_Mid projection in 2060



D = dryland; I = irrigated. AP = Appalachia, CB = Corn Belt, DL = Delta States, LA = Lake States, MN = Mountain States, NE = Northeast, NP = Northern Plains, PA = Pacific, SE = Southeast, and SP = Southern Plains.

The figures illustrate the magnitude of the CO_2 fertilization effect as well as the relative impacts of the effects of temperature change versus precipitation change. The impact of carbon fertilization is variable across crops and regions (revealed by third column relative to first column). Corn, a C_4 crop, experiences a negligible CO_2 impact when irrigated, but a more substantial impact under dryland production, which benefits from the improved water-use efficiency associated with increased CO_2 concentrations when water stress exists (Attavanich et al., 2014). Wheat and soybeans experience substantial yield gains on both dryland and irrigated production due to the combined impacts of improved water-use efficiency and changes in radiation-use efficiency. In all cases, yield impacts vary by region and irrigation method.

The effects of temperature on yields are generally negative across regions for corn, soybeans, and wheat, though there are increased yields experienced in dryland corn and wheat production in the Pacific region (not shown in figure). Precipitation impacts vary and generally are not as significant as those attributable to other elements of climate change. In those cases where significant impacts occur, they are often consistent across crops; in the Northern Plains, for instance, all three crops experience declines in dryland yields as a result of decreased precipitation in those regions.

The net effect of climate change on yields depends on how these elements balance or exacerbate one another. Corn yields, which lack a significant CO_2 boost to radiation-use efficiency, often decline significantly; that drop is almost entirely driven by increased temperature. Under the climate projection illustrated, soybean and wheat yields also always decline (there are climate projections where that is not the case in 2060).

Although crop growth parameters, and the dynamics of the relationship between climate elements and crop growth, are consistent across time periods and climate projections, the net effect on yields changes over time and scenario, as the balance between different elements of climate change varies. Furthermore, the aggregate yield impacts, illustrated here at the regional level, are weighted averages of what is occurring at the field scale for each of REAP's production enterprises, so the magnitude of change is not necessarily representative of what is happening for any single rotation. The results for corn growing in the Corn Belt, for instance, are an average of what is happening to corn yields in a continuous corn rotation and in a corn/soybean rotation (among others). Because the yield impacts of any single element of climate change are dependent on other factors in the crop production system—in particular, water and nutrient constraints—those impacts can vary significantly across production enterprises for the same crop within a single region.

Dryland and Irrigated Production Enterprises

EPIC calculates the yield, crop water use, and environmental implications of a set of field operations representing a specific crop rotation using defined tillage and production practices. These practices include irrigation, fertilizer application rates, and planting and harvest dates. Each of those combinations of rotation/tillage/input use is called a "production enterprise," and each analytical region is characterized by a set of production enterprises that define the choice set for cropland production in that region. A selection of regionally appropriate production enterprises has been derived for each analytical region using the 2007 National Resources

Inventory (NRI) data. Estimates of acreage in each region under specific rotation and irrigation practice were extracted from that data, and production enterprises were designed to reflect that set of production choices. Given the diversity of farming practices, we did not attempt to comprehensively represent production in each region; production enterprises observed on fewer than 25,000 acres within a region, for instance, were not included unless that rotation had historically been more predominant in the region or was pre-existing as a production enterprise in our EPIC database. We also focus our analysis on major field crops, although specialty crops and minor field crops may account for significant land and water resources in some regions. The list of field crop rotations by analytical region used in this analysis can be found in Appendix D.

The creation of irrigated production enterprises for inclusion in the analysis required several simplifying assumptions. Rotations were defined as either dryland or fully irrigated, in which case all crops in that rotation were irrigated; there are no partially irrigated rotations included within the analysis. The amount of irrigation water applied to irrigated rotations is calculated by EPIC, assuming a fixed irrigation water-use efficiency (percentage of applied irrigation water that is consumptively used by the crop) of 75 percent. Applied water is generally less than the full net irrigation requirement of the crop as EPIC allows a small amount of plant water stress; when water stress exceeds the permitted threshold, an irrigation application is triggered. Irrigated rotations are generally fertilized at a higher rate than dryland rotations; in creating irrigated rotations we adjusted nitrogen and phosphorus application according to Agricultural Resource Management Survey (ARMS) data based on the average ratio of irrigated to dryland applications reported by Farm Production Region.[2]

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[2] Applied irrigation water can vary substantially across years, depending on that year's precipitation. The inability of this analysis to vary fertilizer application rate with weather outcomes and applied irrigation levels is a limitation of the analysis.

Appendix D: List of Crop Rotations by Analytical Regions

The choice set for possible rotations within each crop production region was developed based on acreage numbers pulled from the 2007 NRI data, with some additional rotations remaining from prior REAP analyses. Appendix table 6 lists the crop abbreviations used for designating crop rotations in this analysis. The full list of rotations available for one or more crop production regions within each farm production region is given in Appendix table 7. Within each region, those rotations may be available using one or more tillage types (conventional, reduced, or no-till) as well as in dryland and/or irrigated production. Rotations designated by three of the same crop letter (i.e., TTT, WWW) indicate a rotation that is continuously planted in that crop.

Appendix table 6: Legend of crop abbreviations used in designating crop rotations in EPIC and REAP analyses

Abb.	Crop
B	Soybeans
C	Corn
F	Fallow
G	Silage
H	Hay
L	Barley
O	Oats
R	Rice
S	Sorghum
T	Cotton
W	Wheat

Note: EPIC = Environmental Policy Integrated Climate. REAP = Regional Environment and Agriculture Programming.

Appendix table 7: Crop rotations available for one or more crop production regions within the farm production region shown

Region	Rotations available
AP	BBB,BF,BH,BS,BT,BW,BWS,BWT,CB,CBH,CBL,CBS,CBT,CBW,CBWH,CCC,CH,CT,CW,CWH,CWL,CWT,GGG,HF,HHH,TF,TTT,WH,WT,WWW
CB	BBB,BH,BOH,BR,BS,BT,BW,BWH,BWS,BWT,CB,CBH,CBO,CBOH,CBR,CBS,CBT,CBW,CBWH,CBWS,CCC,CH,CO,COH,CT,CW,CWH,CWT,GGG,HHH,LO,RRR,TTT,WH,WWW
DL	BBB,BF,BH,BR,BS,BST,BT,BTR,BW,BWR,BWS,BWT,CB,CBR,CBT,CBW,CCC,CF,CT,CW,CWH,CWT,GGG,HHH,RRR,ST,TR,TTT,WF,WT,WTF
LA	BBB,BH,BL,BO,BOH,BS,BW,BWF,BWH,BWL,CB,CBH,CBL,CBO,CBOH,CBW,CBWH,CBWO,CBWS,CCC,CH,CLH,CO,COH,CW,CWF,CWH,GGG,GH,HF,HHH,LH,OH,WF,WH,WL,WOH,WWW
MN	CBL,CCC,CF,CH,CL,CS,CT,CW,CWF,CWH,CWL,CWS,GGG,HF,HHH,LF,LH,LLL,OH,SF,SSS,TF,TH,TTT,WF,WH,WHF,WL,WLF,WLH,WLOF,WO,WOF,WS,WSF,WT,WWW
NP	BBB,BH,BL,BO,BOH,BS,BW,BWF,BWH,BWL,BWO,BWS,CB,CBH,CBL,CBO,CBOH,CBS,CBW,CBWF,CBWH,CBWL,CBWO,CBWS,CCC,CF,CH,CL,CO,COH,CS,CW,CWF,CWH,CWL,CWO,CWS,CWSF,GGG,HF,HHH,LH,LLL,LO,OF,OH,OOO,SF,SH,SO,SSS,WF,WH,WHF,WL,WLF,WLH,WLO,WO,WOF,WOH,WS,WSF,WSOF,WWW
NE	BBB,BH,BW,CB,CBH,CBL,CBO,CBW,CBWH,CCC,CF,CH,CL,CO,COH,CW,CWH,CWL,CWO,GGG,GH,HHH,LH,OH,OOO,SH,WH,WOH
PA	CCC,CF,CH,CL,CO,CT,CW,CWF,CWH,CWT,GGG,HF,HHH,LF,LH,LLL,OH,OOO,RF,RRR,TH,TTT,WF,WH,WHF,WL,WLF,WLH,WOF,WT,WTH,WWW
SE	BBB,BF,BS,BT,BW,BWT,CB,CBT,CBW,CBWL,CCC,CF,CH,CT,CW,CWF,CWT,GGG,HHH,TF,TH,TO,TTT,WF,WOH,WT,WTF,WWW
SP	BBB,BST,BT,BW,CB,CBS,CBT,CBW,CCC,CF,CS,CST,CT,CW,CWF,CWO,CWS,CWT,GGG,HHH,OF,OOO,RF,RRR,SF,SH,SO,SSS,ST,TF,TH,TO,TTT,WF,WH,WL,WO,WOF,WS,WSF,WST,WT,WTF,WTH,WWW

AP = Appalachia, CB = Corn Belt, DL = Delta States, LA = Lake States, MN = Mountain States, NE = Northeast, NP = Northern Plains, PA = Pacific, SE = Southeast, and SP = Southern Plains.

Appendix E: Establishing a Reference Scenario to 2080

The Regional Environment and Agriculture Programming (REAP) model is a partial-equilibrium representation of major U.S. agricultural production that measures deviations from a given set of prices, acreage, yields, and transformation parameters. This set of values is used to calibrate the model to enforce economic and physical consistency between the reference values. In a typical REAP application, one or more policy, technology, or market shock is postulated that allows REAP to quantify deviations from the reference. Because the desired outcome is the impact of the shock on agricultural production, the ideal reference scenario will be technology- and policy-neutral, so that assumptions implicit (or explicit) in the reference scenario do not significantly influence the impact of the shock. In previous analyses, the reference scenario has come directly from the USDA Agricultural Projections, a conditional scenario that makes specific assumptions about macroeconomic, agricultural, and trade policies and assumes no domestic or external shocks that would affect global agricultural markets. USDA projections look ahead only 10 years into the future, so they are of limited use when addressing agricultural issues that are inherently longer term, such as climate change.

To enable application of REAP to issues related to climate change, we have developed a reference scenario for each of the analysis years (2020, 2040, 2060, 2080) used in this report. The USDA Agricultural Projections are used as a starting point to develop a reference scenario that is physically and economically consistent and suitable for use in REAP. Simple extrapolation of individual yield, price, and acreage trends of the USDA projection does not capture the complexity of the relationships of crop production, consumption, and land-use change over time. Instead, we used the USDA projections as though they were an observed data set that has the current policy and technology environment embedded in it, without the influence of climate change, shocks to global agricultural supply and demand, or the economic system as a whole.

The method involves a multistep process. First, constant elasticity of demand curves for domestic consumption, exports, processing, and storage for each of the major crop and livestock commodities were estimated using the last 5 years (the monotonic portion) of the USDA projections and a set of long-run elasticities. Crop yields were assumed to grow at a constant rate equal to 0.6 percent per year. The projected yield growth is assumed to be attributable to improved cultivars and farming systems and not specifically to either heat or drought tolerance. In the EPIC modeling, crop growth parameters related to temperature and drought tolerance are held constant across climate scenarios and analysis years. REAP then adjusts the resulting EPIC yields in each analysis year to reflect the assumed technology increases over time.

The estimated demand curves for marketed outputs in REAP were also projected out to 2080. The full set of demand curves was then used to formulate the objective function in a model that maximizes consumer and producer surplus, and enforces market clearing in each period. Because this direct approach produces results in which exogenous yield growth, prices, and acreage change are not very consistent (for example, some crops might have high planted-acreage levels at low prices compared to other crops) and leads to an unlikely low value of total planted acres, a further restriction fixed the total crop acreage in each period at the 2020 value. This requirement is consistent with a "neutral" scenario that assumes no significant shocks that will greatly change current land use patterns, and assumes that technological innovation will keep up with price and planted acreage.

Appendix tables 8-11 show, respectively, the reference levels of planted acreage, farm-gate crop price, export quantity, and crop yield. One noticeable trend is the increase over the projection period of corn acres that is mirrored by a decline in wheat acres. This is a consequence of substantial growth in demand for corn exports and livestock feed. Demand for wheat is fairly steady over this time, leading to a decline in planted acreage over time as yields increase. Appendix tables 12-14 show the levels of production, exports, and prices for livestock products. Trends follow population growth combined with relative increases in the share of meat products in diets.

The reference market conditions used for each analysis year are invariant to climate scenario. We did not attempt to reconcile the underlying assumptions of each SRES emissions scenario (regarding global population, etc.) to our assumptions about world demand for U.S. products. Nor did we consider the effect of shifting climate conditions on global commodity supply and demand; U.S. export elasticities are assumed fixed across climate futures, though levels of exports may vary as price varies. Modeling the impact of climate change on global elasticities of demand would have been beyond the scope of our analysis and—because REAP is focused on domestic market conditions and is very coarse in its treatment of "rest of the world" trade conditions—would not have produced much in terms of increased precision.

Appendix table 8: Planted acres by crop under the reference scenarios

	Planted acres (million)			
	2020	2040	2060	2080
Barley	3.2	3.0	2.9	2.7
Corn	91.5	96.8	101.7	106.1
Cotton	11.7	11.9	12.2	12.2
Oats	3.0	3.0	2.9	2.8
Rice	3.3	3.5	3.6	3.6
Sorghum	5.6	4.3	3.5	2.9
Soybeans	78.4	77.2	76.9	77.4
Wheat	51.8	48.6	44.2	39.8

Appendix table 9: Price by crop under the reference scenarios

	Price ($/bushel unless otherwise noted)			
	2020	2040	2060	2080
Barley	4.93	5.55	6.17	6.80
Corn	4.28	4.89	5.51	6.12
Cotton (*$/lb*)	0.74	0.90	1.07	1.22
Oats	2.56	2.80	3.03	3.26
Rice (*$/cwt*)	13.81	18.26	22.82	27.47
Sorghum	3.94	4.12	4.23	4.33
Soybeans	10.35	10.78	11.22	11.65
Wheat	5.60	6.11	6.59	7.06

Appendix table 10: Export quantity by crop under the reference scenarios

Exports (million bushels unless otherwise noted)				
	2020	2040	2060	2080
Barley	10	10	10	10
Corn	2,348	3,592	5,393	8,018
Cotton (*million lbs*)	15,670	18,448	21,575	25,076
Oats	3	3	3	3
Rice (*million cwt*)	134	155	175	194
Sorghum	202	218	218	217
Soybeans	1,761	2,111	2,563	3,166
Wheat	902	894	881	870

Appendix table 11: Crop yields under the reference scenarios

Crop yield (bu/acre unless otherwise noted)				
	2020	2040	2060	2080
Barley	72.1	81.2	91.3	103.5
Corn	175.8	198.0	222.8	252.4
Cotton (*lb/acre*)	868.4	978.4	1,100.9	1,247.2
Oats	68.9	77.6	87.3	98.9
Rice (*cwt/acre*)	76.5	86.2	97.0	109.9
Sorghum	67.5	76.1	85.6	97.0
Soybeans	46.8	52.8	59.4	67.3
Wheat	46.7	52.6	59.2	67.1

Appendix table 12: Livestock production under the reference scenarios

Production (million lbs unless otherwise noted)				
	2020	2040	2060	2080
Beef	27,985	36,763	45,541	54,319
Pork	24,915	30,219	35,523	40,827
Turkey	6,595	8,555	10,515	12,475
Broilers	41,820	55,414	69,008	82,602
Eggs (*million dozen*)	8,332	9,974	11,616	13,258
Milk (*billion lbs*)	212.8	262.8	312.8	362.8

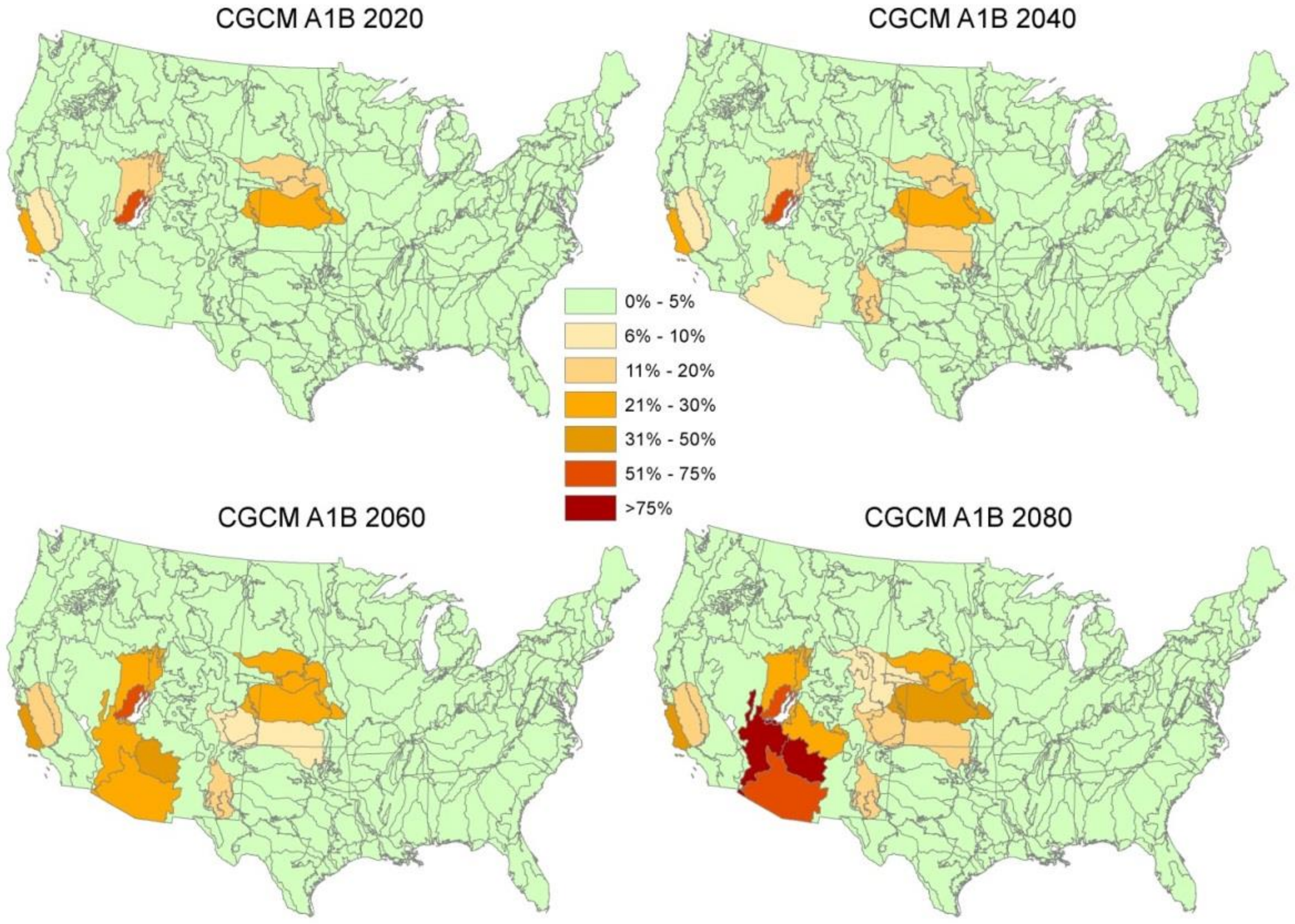
Appendix table 13: Livestock product exports under the reference scenarios

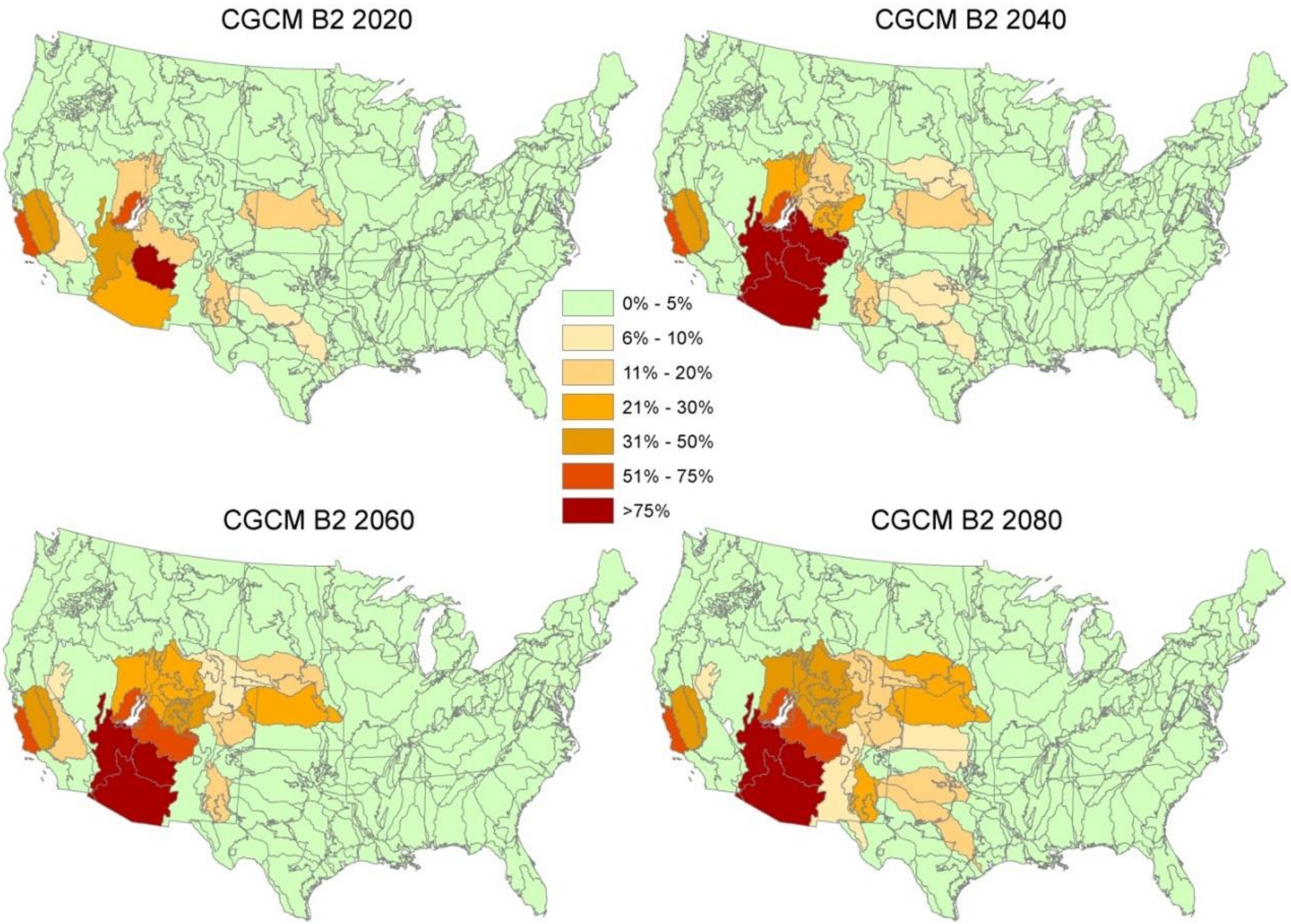
Livestock exports (million lbs)				
	2020	2040	2060	2080
Beef	2,983	4,103	5,223	6,343
Pork	5,526	7,514	9,502	11,490
Turkey	674	870	1,066	1,262
Broilers	6,660	8,258	9,856	11,454
Eggs (*million dozen*)	230	290	350	410

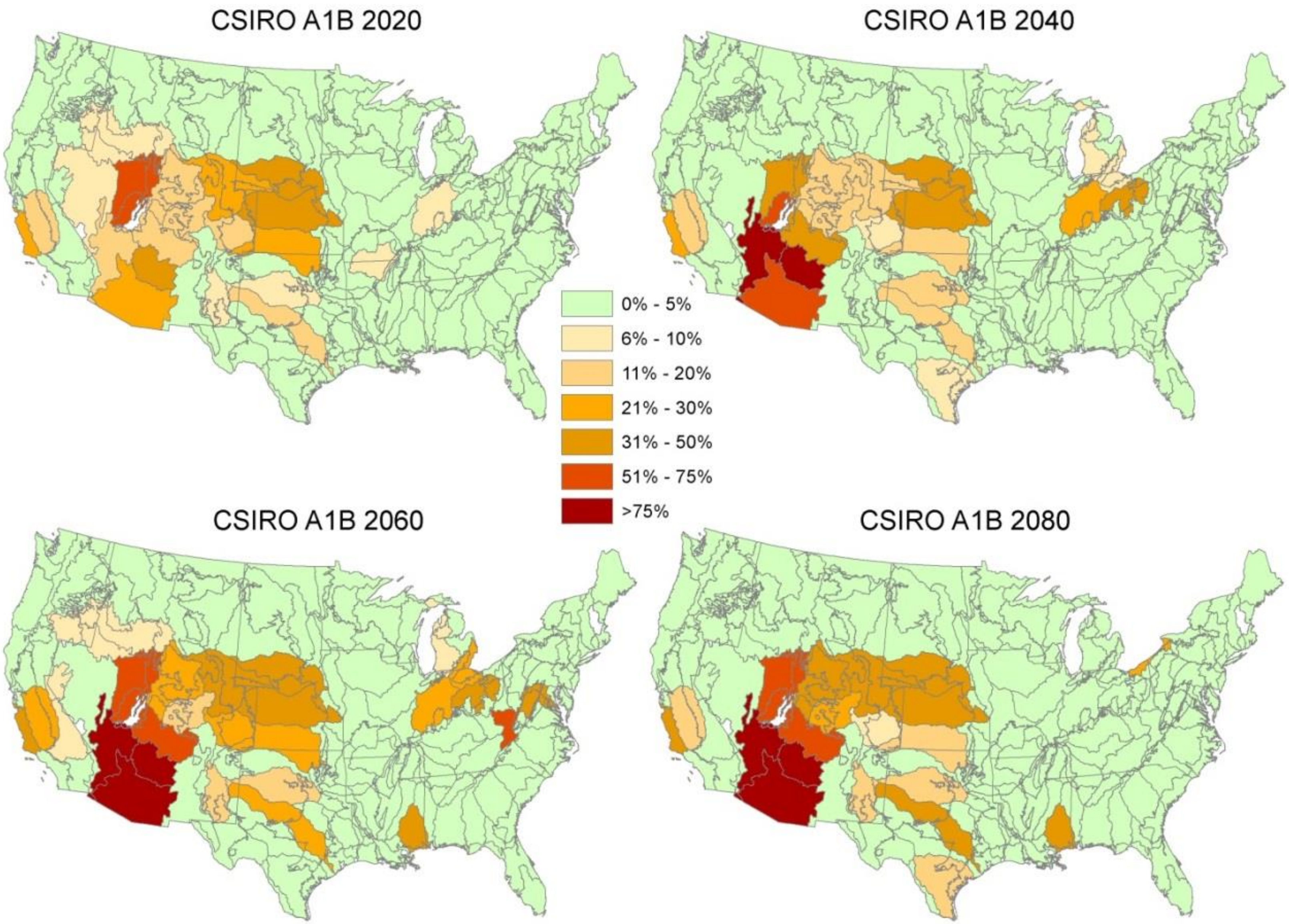
Appendix table 14: Livestock product prices under the reference scenarios

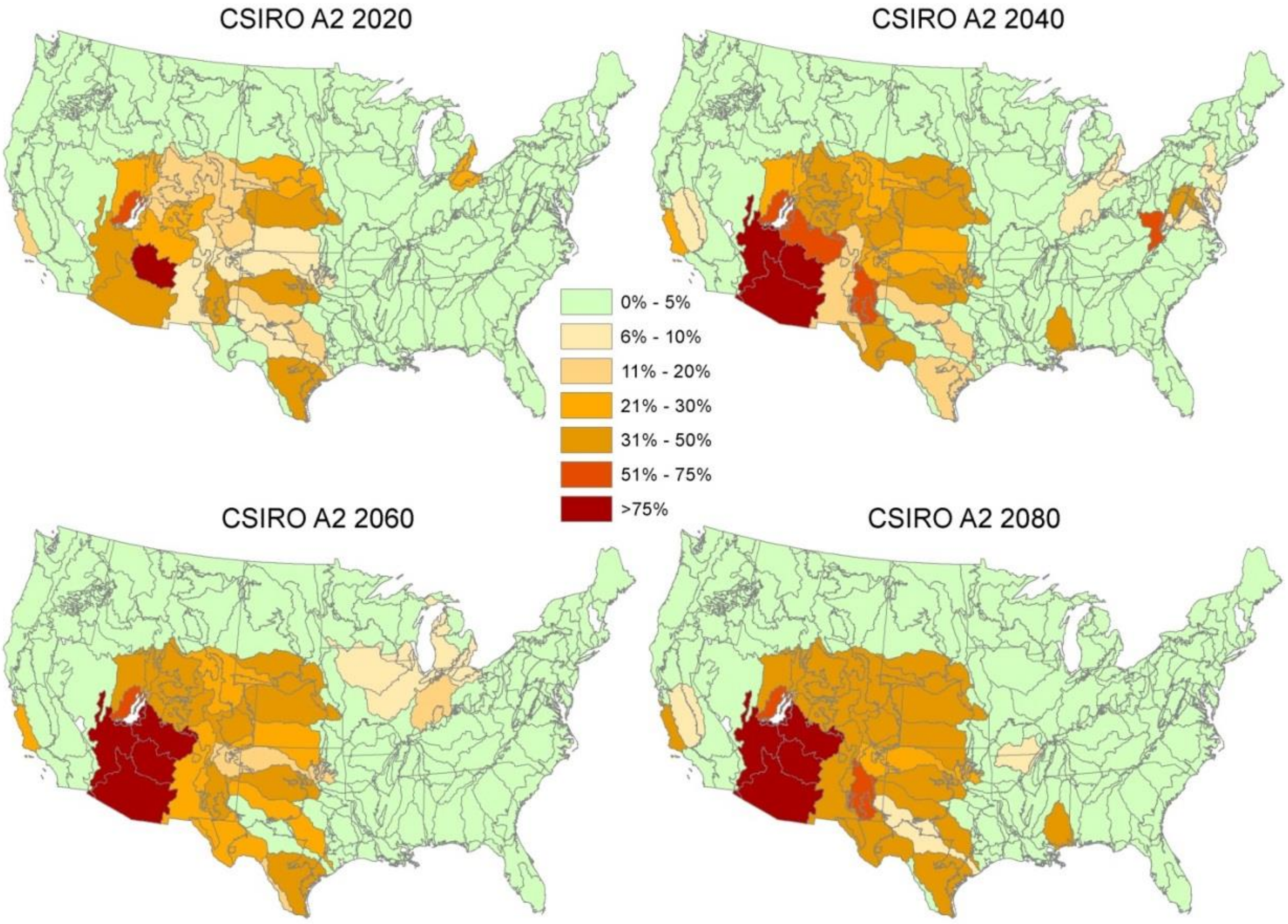
Livestock product prices					
		2020	2040	2060	2080
Beef cattle	(*$/cwt*)	97.78	106.86	115.94	125.02
Hogs	(*$/cwt*)	56.25	81.25	106.25	131.25
Turkeys	(*cents/lb*)	55.0	62.2	69.4	76.6
Broilers	(*cents/lb*)	61.2	82.4	103.6	124.8
Eggs	(*cents/dozen*)	97.2	113.2	129.2	145.2

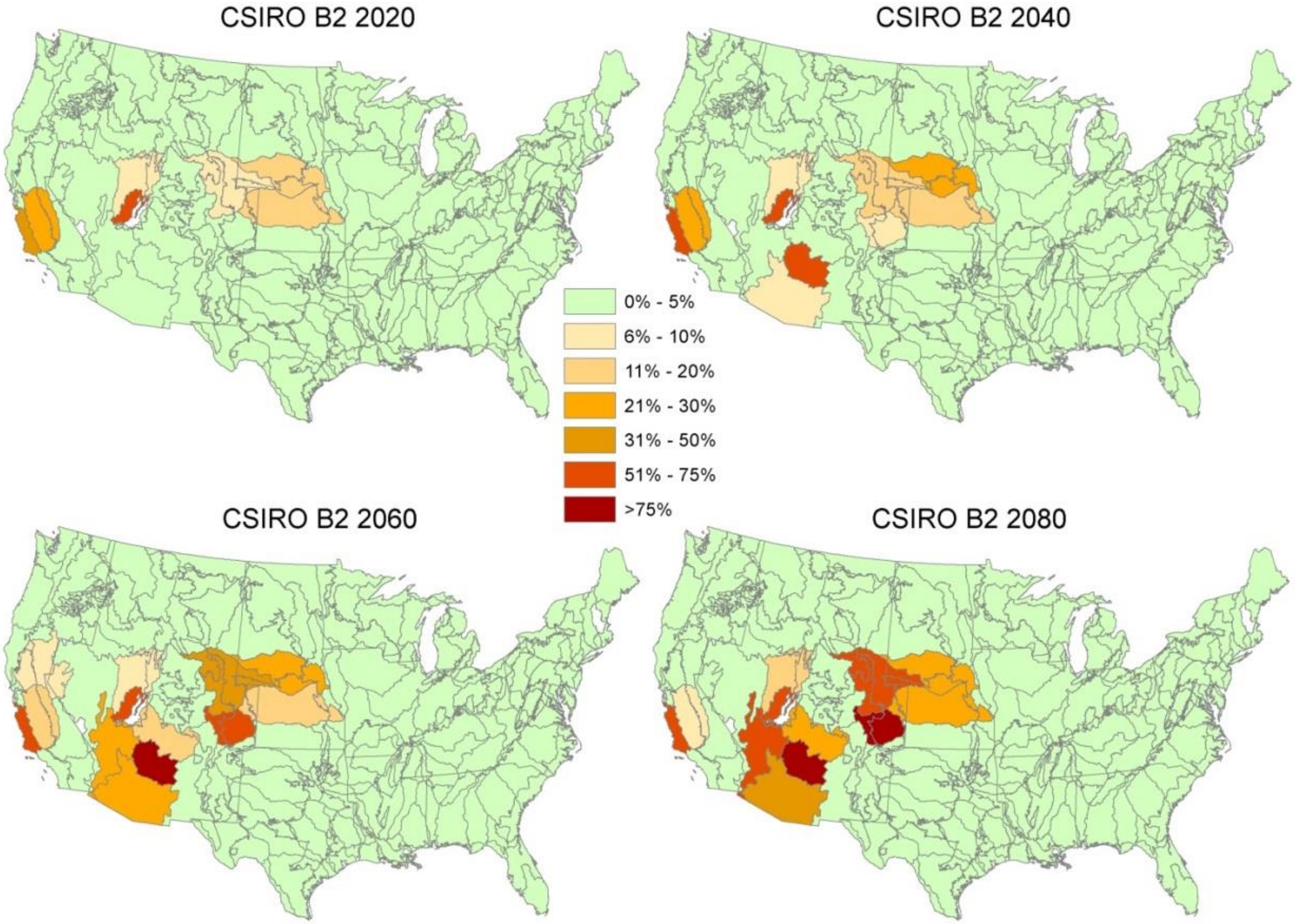
Appendix F: Surface-Water Supply Reductions Under Climate Change Projections

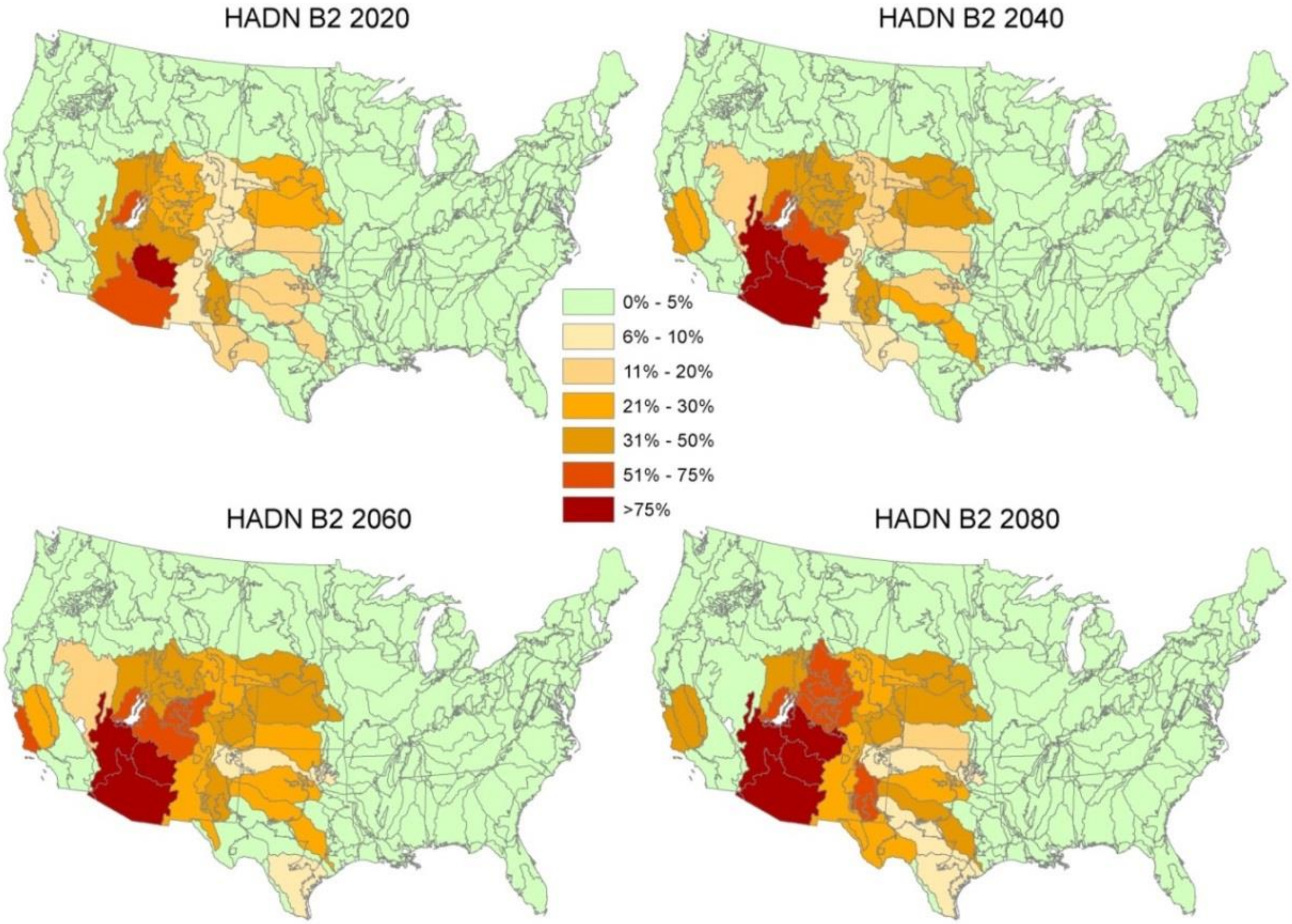


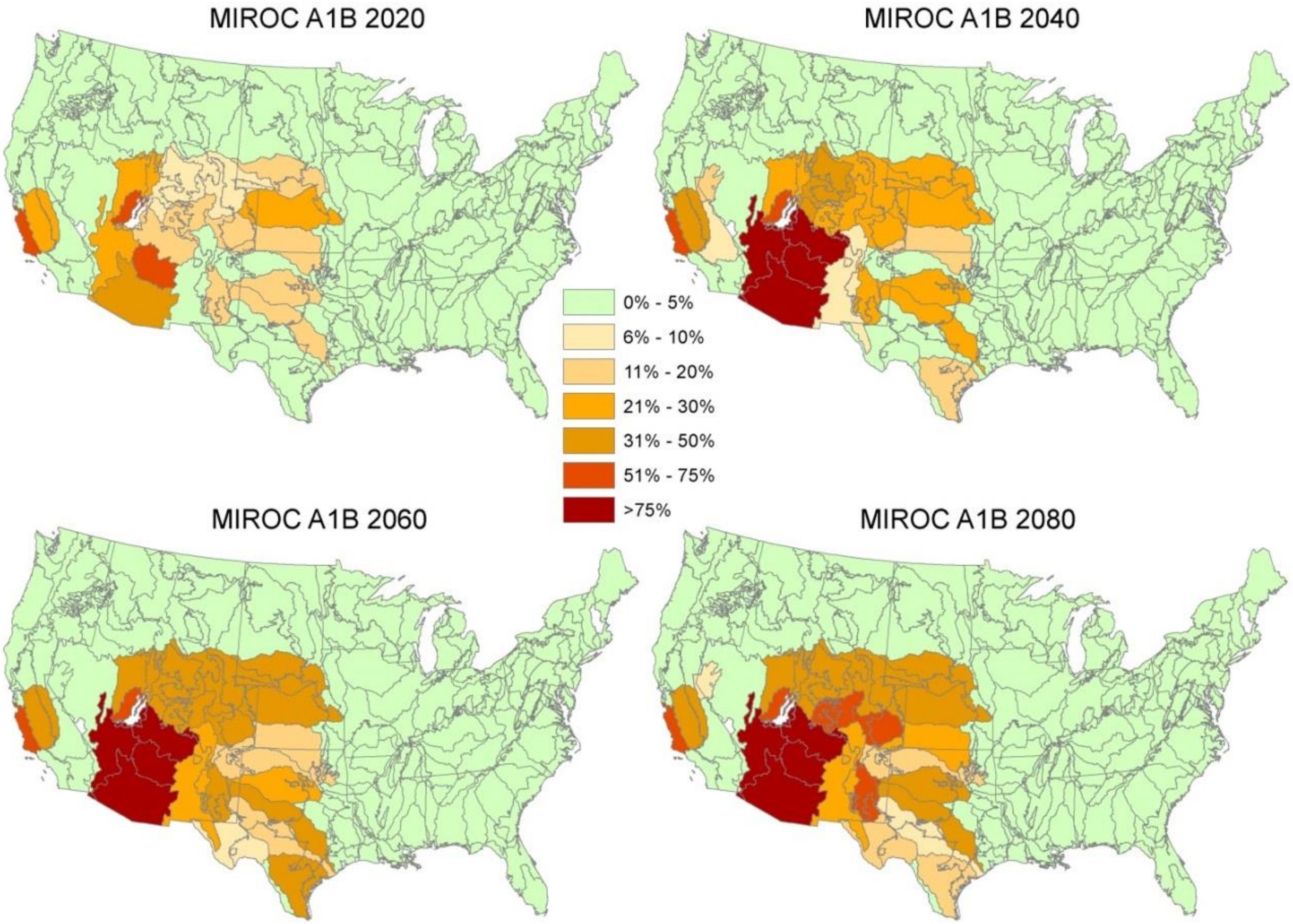

CGCM B2 2020
CGCM B2 2040
0% - 5%
6% - 10%
11% - 20%
21% - 30%
31% - 50%
51% - 75%
>75%
CGCM B2 2060
CGCM B2 2080


CSIRO A1B 2020
CSIRO A1B 2040
CSIRO A1B 2060
CSIRO A1B 2080
0% - 5%
6% - 10%
11% - 20%
21% - 30%
31% - 50%
51% - 75%
>75%


CSIRO A2 2020
CSIRO A2 2040
0% - 5%
6% - 10%
11% - 20%
21% - 30%
31% - 50%
51% - 75%
>75%
CSIRO A2 2060
CSIRO A2 2080


CSIRO B2 2020
CSIRO B2 2040
0% - 5%
6% - 10%
11% - 20%
21% - 30%
31% - 50%
51% - 75%
>75%
CSIRO B2 2060
CSIRO B2 2080

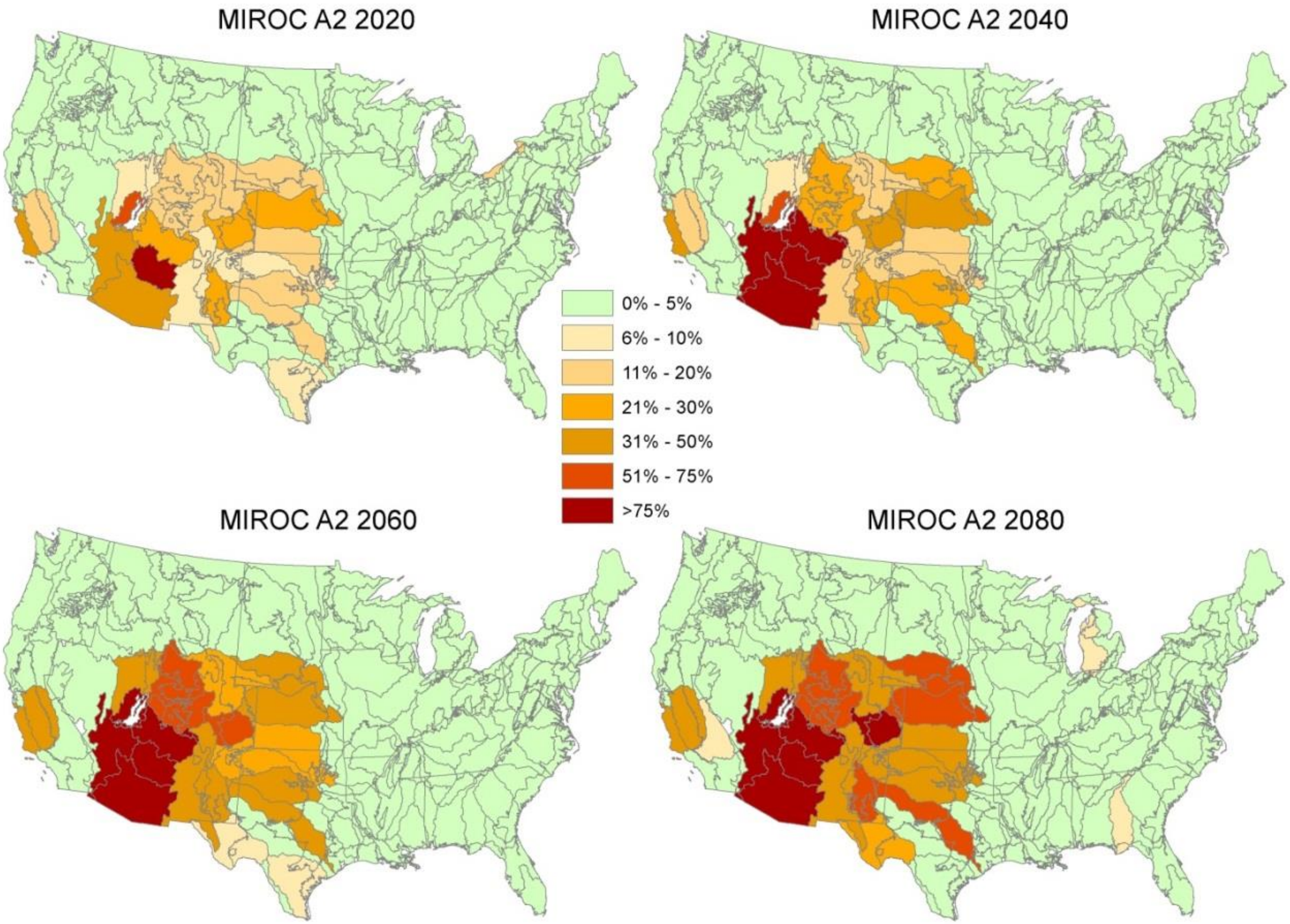

HADN B2 2020
HADN B2 2040
0% - 5%
6% - 10%
11% - 20%
21% - 30%
31% - 50%
51% - 75%
>75%
HADN B2 2060
HADN B2 2080


MIROC A1B 2020

MIROC A1B 2040

MIROC A1B 2060

MIROC A1B 2080


MIROC A2 2020

MIROC A2 2040

MIROC A2 2060

MIROC A2 2080

Appendix G: Biophysical Yield Impacts of Climate Change in 2060

Appendix table 15: Biophysical impacts of climate change scenarios on barley yields, dryland and irrigated, 2060

Region	Irr. system	Ref yield (bu/ acre)	Average CC yield (bu/ acre)	Percent change in barley yields, 2060								
				CGCM_ Low	CSIRO _Low	HADN _Low	CGCM _Mid	CSIRO _Mid	MIROC _Mid	CGCM_ High	CSIRO_ High	MIROC _High
AP	D	91.5	97.1	-4.9	6.7	7.7	-3.7	5.3	16.3	1.2	9.7	16
CB	D	91.6	73	-12.1	-15.2	-21.3	-8	-29.6	-22.5	-26.7	-25.9	-21.9
LA	D	64.6	60.1	1.9	-4.6	-12.1	6.5	-26	-12.1	-6.3	-6.2	-3.5
MN	D	61.5	71.7	23.5	15.8	-19.5	36.6	-14.1	15.9	45.6	25.3	19.4
MN	I	125.2	115.8	-1	-10.2	-17.7	-3	-14.2	-5.1	-8.7	-10.8	3.3
NP	D	69.9	70.8	11.2	-3.6	-9.8	19.5	-30.4	-11	9.6	12.2	14
NP	I	104.5	94.6	2.4	-12.4	-16.6	0.7	-28	-13.1	-7.8	-7.5	-2.4
NE	D	83.2	94.9	11.2	16.7	6.3	15.1	9.1	18.7	16.7	17.5	14.7
PA	D	72.1	101.8	29	25.1	11.5	52.9	23.7	60.1	67.4	54.8	46
PA	I	142.3	134.3	0.3	-12.5	-13.6	-2.5	-10.6	-3.1	-3.7	-8.2	3.3
SE	D	70	76	19.2	4.3	8.6	6.9	8.4	8	5.2	6.4	10.1
SP	I	70.1	73.2	-0.1	-2.5	4.3	15.5	-2.1	5.2	-2.3	13.9	7.4

Note: AP = Appalachia, CB = Corn Belt, DL = Delta States, LA = Lake States, MN = Mountain States, NE = Northeast, NP = Northern Plains, PA = Pacific, SE = Southeast, and SP = Southern Plains.

Appendix table 16: Biophysical yield impacts of climate change scenarios on cotton yields, dryland and irrigated, 2060

				Percent change in cotton yields, 2060								
Region	Irr. system	Ref yield (bales/ acre)	Average CC yield (bales/ acre)	CGCM_ Low	CSIRO _Low	HADN _Low	CGCM _Mid	CSIRO _Mid	MIROC _Mid	CGCM_ High	CSIRO _High	MIROC _High
AP	D	2	2	1.6	-5.1	-7.6	4.1	-4.4	-6.5	-3.8	-4	-13.9
AP	I	2.2	1.9	-2.1	-6.3	-9.6	0.9	-13.1	-15.8	-17.4	-17.7	-19.8
CB	D	2.4	2.1	1.1	-3.7	-13.1	5.4	-15.1	-15.2	-15.1	-16.9	-33.5
CB	I	2.7	2.3	-1.5	-9.1	-15.9	-2.1	-13.4	-17.8	-18.7	-18.9	-28.1
DL	D	2.4	2.1	2.4	-2	-12.4	-3.8	-10.4	-15.1	-18.1	-10.1	-21.4
DL	I	2.5	2.3	-0.5	-5.5	-10.6	-4.8	-3	-10	-12	-5.9	-16.9
MN	I	3.6	3.2	-8.2	-1.8	-12.5	-5.9	-7.4	-14	-10.7	-6	-22.1
PA	D	0.2	0.3	32.9	26.3	34	74.1	151.3	48.9	36.8	193.4	-13.9
PA	I	4	3.9	-2.2	-6	-3.7	-0.5	0.2	-4.7	-4.1	0.7	-1
SE	D	2	1.9	-8.4	-5.3	-3	2.4	-11.9	-8.3	-10.9	4	-24.4
SE	I	2.6	2.5	-0.7	-2.8	-4.8	-4	-7.8	-11.6	-12.8	-1.9	-10.3
SP	D	1.2	1.2	13	19.1	-12.2	17.1	23.2	-22	4.9	-17.1	-25.5
SP	I	2.5	2.5	6	5.7	-2.6	3.1	6.9	-2.4	-2.9	-3.2	-7.4

Note: AP = Appalachia, CB = Corn Belt, DL = Delta States, LA = Lake States, MN = Mountain States, NE = Northeast, NP = Northern Plains, PA = Pacific, SE = Southeast, and SP = Southern Plains.

Appendix table 17: Biophysical impacts of climate change scenarios on hay yields, dryland and irrigated, 2060

				Percent change in hay yields, 2060								
Region	Irr. system	Ref yield (tons/ acre)	Average CC yield (tons/ acre)	CGCM _Low	CSIRO _Low	HADN _Low	CGCM _Mid	CSIRO _Mid	MIROC _Mid	CGCM_ High	CSIRO_ High	MIROC _High
AP	D	2.8	2.7	0.3	2.5	-5	8.1	-3.4	-10.4	-4.6	-8.1	-8.1
CB	D	2.9	2.5	-2.6	-8.8	-18.9	7.9	-18.9	-22.5	-14.6	-19.1	-22
DL	D	2.6	2.3	1.3	-4	-11.1	0.1	-14.7	-20.1	-17.7	-20.4	-22.6
LA	D	3.4	3.5	13.7	-0.4	-12.4	13.6	-2.9	-0.6	8.2	4.1	-1.7
LA	I	4.1	4.2	14.9	-4.8	-12	13.4	-4.8	1.8	3.6	-0.4	7.6
MN	D	1.5	2	41.9	42.9	-15.9	57.9	10.9	12.6	72.5	46.5	18
MN	I	5	5.5	15.5	19	-7.2	11	6.1	11.2	15.3	4.6	9.4
NP	D	2.4	2.5	16	-9.4	-25.5	24.6	-11.6	-12	21.9	11.6	3.5
NP	I	4.6	4.4	12	-2.3	-21.6	13.1	-5.7	-11.9	-3.9	-6	-7.7
NE	D	2.7	2.9	11.1	6.6	-7	17.5	5.9	8.2	6.8	2.9	10.4
PA	D	4.9	4.6	-7.3	-8.1	-31.2	-8.5	-16.2	8.5	7.7	-3.7	-2.4
PA	I	6.3	6.7	10.9	3.4	-3.4	5	7.6	8.4	13.5	2	7.9
SE	D	3.2	3	7.1	1.5	0.6	8	-4.6	-16.4	-10.5	-7.3	-12.1
SE	I	3.7	3.4	-1.4	-5.3	-9.5	-4.2	-10.2	-18.2	-16.2	-13.9	-5.5
SP	D	2.2	2.7	17.7	20.6	19.3	18	30.2	24.8	27.4	27	22.9
SP	I	2	2.8	30.1	30.8	40.5	23.8	38	49.5	39.8	42.4	46.9

Note: AP = Appalachia, CB = Corn Belt, DL = Delta States, LA = Lake States, MN = Mountain States, NE = Northeast, NP = Northern Plains, PA = Pacific, SE = Southeast, and SP = Southern Plains.

Appendix table 18: Biophysical impacts of climate change scenarios on oat yields, dryland and irrigated, 2060

				Percent change in oat yields, 2060								
Region	Irr. system	Ref yield (bu/ acre)	Average CC yield (bu /acre)	CGCM_ Low	CSIRO _Low	HADN _Low	CGCM _Mid	CSIRO _Mid	MIROC _Mid	CGCM_ High	CSIRO _High	MIROC _High
CB	D	89.4	57.8	-24.4	-27.4	-42	-15.5	-48.2	-37.8	-48	-40.8	-34
LA	D	87.5	60.5	-16.3	-23.8	-35.1	-12.5	-43.7	-38.1	-38.7	-37.5	-32.3
LA	I	99.3	63.1	-21	-29.6	-39.8	-19.2	-49.1	-43.3	-43.9	-44.2	-38.3
MN	D	68.7	76.5	24.4	9.1	-24.7	31	-15.8	10.4	28.4	17.9	22.1
MN	I	119.3	91.6	-12	-15.5	-34.7	-18.1	-29.7	-23.2	-29.5	-26.9	-19.7
NP	D	85	75	1	-16.7	-29.7	8.1	-35.7	-20.2	-2.9	-6.6	-3.1
NP	I	106.7	91.6	2.3	-19.1	-29	-3.4	-26.2	-14.5	-18.7	-11.2	-7.3
NE	D	83.3	65.4	-2.4	-13.6	-24.3	-9.9	-30.5	-30	-26.9	-25.3	-30.9
PA	D	88.9	79.5	-25.7	-9.6	-18.6	-2.4	-0.6	-19.5	-23.4	27.7	-23
PA	I	146.5	137.5	-4.3	-11.7	-9.4	-4.9	-14.7	-4.9	-8.8	5.2	-1.6
SE	D	78.6	78.2	9.8	-4.4	-0.2	2	2.8	-2.4	-2.2	-7	-2.9
SP	D	58.4	58.5	8.6	6.1	-8.2	21.5	-10.7	-14.4	7.4	10.4	-19.6
SP	I	89	88	0.4	-2.4	1.6	4.2	-1	-4.2	-6.1	0.9	-4.1

Appendix table 19: Biophysical impacts of climate change on rice yields, irrigated only, 2060

				Percent change in rice yields, 2060								
Region	Irr. system	Ref yield (cwt/ acre)	Average CC yield (cwt/ acre)	CGCM_ Low	CSIRO _Low	HADN _Low	CGCM _Mid	CSIRO _Mid	MIROC _Mid	CGCM_ High	CSIRO _High	MIROC _High
CB	I	89.9	82.4	0.4	-0.3	-12.5	2.1	-3.1	-13.7	-14	-7.2	-26.5
DL	I	91.1	84.4	-0.7	-0.9	-9.6	-3	-1.7	-11.5	-14.4	-3.2	-21.1
PA	I	110.4	106.9	-0.5	-5.2	-2.3	-6.8	-1.6	-4.9	-3.4	-2.8	-1
SP	I	101.4	92	-0.3	-0.3	-15.8	-10.4	-8.5	-10.4	-20.1	-6.4	-11

Note: cwt = hundredweight.

AP = Appalachia, CB = Corn Belt, DL = Delta States, LA = Lake States, MN = Mountain States, NE = Northeast, NP = Northern Plains, PA = Pacific, SE = Southeast, and SP = Southern Plains.

Appendix table 20: Biophysical impacts of climate change on silage yields, dryland and irrigated, 2060

				Percent change in silage yields, 2060								
Region	Irr. system	Ref yield (tons/ acre)	Average CC yield (tons/ acre)	CGCM_ Low	CSIRO _Low	HADN _Low	CGCM _Mid	CSIRO _Mid	MIROC _Mid	CGCM_ High	CSIRO _High	MIROC _High
AP	D	16.3	15.2	-0.5	-3.5	-8.3	3.2	-8.9	-7.3	-4.7	-10.8	-15.5
CB	D	16.7	15.6	2.6	-5.2	-15.7	13.9	-19.8	-8.1	-0.4	-10.6	-19.1
DL	D	14	11.8	-1.3	-4.9	-13	-10.9	-16.4	-19.6	-22.3	-18.1	-32.1
LA	D	18.7	17.3	0.2	-5.1	-8.9	4	-13.7	-12.9	-3.6	-10.6	-17.4
MN	I	25.9	21.4	-8.8	-12.4	-20.5	-16.2	-21.5	-19.7	-19.6	-17.4	-20
NP	D	9.3	8.1	2.9	-25.1	-38.8	25.7	-22.3	-25.2	-3.2	-4	-27.2
NP	I	18.7	16.9	-1.7	-6	-18.1	2.3	-15.5	-12	-8.5	-9.5	-14.2
NE	D	18.1	18	7.7	1	-2.8	6.3	-3.8	-3.4	-0.4	-5.9	-7.8
PA	D	26.1	35.3	24.5	114.9	18.5	24.8	17.2	31	24.2	31.2	30.8
PA	I	18.3	16.1	-9.2	-13.9	-14	-11.8	-8.3	-15.2	-14.2	-8.1	-11.1
SE	D	18	16	-5.3	-8.5	-2.3	-3.4	-16.4	-12.6	-14.7	-7.1	-29.9
SP	D	12.7	12.2	13.9	9.2	-11.9	11.4	-10.2	-19.4	-5.4	-7.3	-19.6
SP	I	21.6	19.5	-2.2	-0.3	-15.4	-6.9	-4.4	-11.2	-12.5	-12.5	-20.2

Note: AP = Appalachia, CB = Corn Belt, DL = Delta States, LA = Lake States, MN = Mountain States, NE = Northeast, NP = Northern Plains, PA = Pacific, SE = Southeast, and SP = Southern Plains.

Appendix table 21: Biophysical impacts of climate change on sorghum yields, dryland and irrigated, 2060

				Percent change in sorghum yields, 2060								
Region	Irr. system	Ref yield (bu/ acre)	Average CC yield (bu/ acre)	CGCM_ Low	CSIRO _Low	HADN _Low	CGCM _Mid	CSIRO _Mid	MIROC _Mid	CGCM_ High	CSIRO _High	MIROC _High
AP	D	86.4	77	-4.1	-6.3	-12.5	-0.1	-14.7	-11.5	-10.8	-14.3	-23.6
CB	D	92.2	77.1	-6.5	-11.2	-22.5	-1	-20.6	-18.6	-18.2	-20.8	-27.9
DL	D	108.9	104.9	-0.1	-1.3	-4.6	-4.5	-1.3	-3.8	-8.2	-3.9	-4.8
DL	I	103.3	105	0	1.7	0.2	-0.8	6.7	3.8	0.4	0.7	2.1
LA	D	86.5	79.8	1.8	-4.6	-6.1	-3.3	-14.9	-10.4	-4.2	-9.2	-19.1
MN	D	46.2	39.9	-12.7	1.9	-31	-0.4	-7.2	-23.5	-8.1	-3.6	-38.4
MN	I	93.5	80.5	-3.2	-11.9	-17.3	-0.6	-19.1	-17.1	-20.3	-8	-26.9
NP	D	69.1	59.9	-3.6	-16.5	-33.3	10.7	-20.1	-14.7	-8	-5.4	-28.5
NP	I	102.8	85.9	-7.3	-8.1	-27.5	-3.7	-20.2	-21.1	-18.7	-12.9	-28.1
NE	D	86.4	85	4.4	2.1	-2.2	6.7	-6.7	-3.3	-1.2	-4.4	-10.5
SE	D	57.5	50.9	-3.1	-9.4	-9	1	-19.7	-9.4	-9.7	-12.7	-31.5
SP	D	62.4	58.9	2.1	10.6	-13.7	12.9	6.2	-20.9	-6.6	-14.7	-26
SP	I	108.5	100.2	-3.1	-0.6	-11	-3.7	-5.4	-8.3	-11.8	-10.4	-14.8

Note: AP = Appalachia, CB = Corn Belt, DL = Delta States, LA = Lake States, MN = Mountain States, NE = Northeast, NP = Northern Plains, PA = Pacific, SE = Southeast, and SP = Southern Plains.

Appendix H: Regional Irrigation Demand Under Climate Change When Production Acreage Is Fixed

Under the reference climate conditions, irrigated water demand increases roughly 10 percent over the analysis period (2020 to 2080)—from 77.14 million acre-feet to 85.68 million acre-feet. This outcome reflects the acreage assumptions underlying the reference production scenarios developed for each time period. Appendix tables 21-24 illustrate how applied irrigation water changes when production acreage is fixed by region, crop, and cropping system. Changes in applied irrigation under the climate change projections in each period are due to biophysical impacts on crop water demand under reference production patterns. Declines are shown in red.

Appendix table 22: Regional applied irrigation amounts under reference and climate change scenarios for 2020 (with fixed acreage allocation)

Applied irrigation water, million acre-feet, 2020											
Region	Reference	Average CC	CGCM _Low	CSIRO _Low	HADN _Low	CGCM _Mid	CSIRO _Mid	MIROC _Mid	CGCM _High	CSIRO _High	MIROC _High
AP	0.15	0.16	0.14	0.16	0.15	0.14	0.17	0.18	0.15	0.17	0.18
CB	1.47	1.57	1.49	1.4	1.39	1.53	1.75	1.41	1.62	1.71	1.8
DL	8.43	9.39	8.52	7.79	9.13	8.71	10.25	9.34	9.71	9.78	11.32
LA	0.58	0.58	0.57	0.54	0.54	0.64	0.56	0.58	0.55	0.61	0.6
MN	24.25	25.07	25.11	26.04	25.58	24.43	26.04	25.44	24.52	23.37	25.09
NP	14.84	14.69	15.39	15.57	14.76	14.28	14.77	14.35	13.79	14.4	14.86
NE	0.1	0.1	0.08	0.11	0.09	0.1	0.1	0.11	0.09	0.1	0.11
PA	20.21	19.94	20.37	20.55	20.52	19.8	20.28	19.83	19.36	19.03	19.74
SE	0.45	0.49	0.52	0.52	0.45	0.47	0.47	0.46	0.44	0.49	0.57
SP	6.66	6.82	6.73	6.33	7.22	6.57	6.43	7.34	6.56	7.34	6.9
Total	77.14	78.81	78.92	79.01	79.83	76.67	80.82	79.04	76.79	77	81.17

Note: AP = Appalachia, CB = Corn Belt, DL = Delta States, LA = Lake States, MN = Mountain States, NE = Northeast, NP = Northern Plains, PA = Pacific, SE = Southeast, and SP = Southern Plains.

Appendix table 23: Regional applied irrigation amounts under reference and climate change scenarios for 2040 (with fixed acreage allocation)

Applied irrigation water, million acre-feet, 2040											
Region	Reference	Average CC	CGCM _Low	CSIRO _Low	HADN _Low	CGCM _Mid	CSIRO _Mid	MIROC _Mid	CGCM _High	CSIRO _High	MIROC _High
AP	0.14	0.15	0.14	0.15	0.13	0.12	0.14	0.19	0.14	0.16	0.17
CB	1.52	1.54	1.55	1.46	1.46	1.32	1.45	1.57	1.53	1.84	1.71
DL	8.74	9.65	9.1	8.07	9.57	8.3	8.82	11.06	9.38	10.81	11.72
LA	0.63	0.57	0.62	0.56	0.57	0.57	0.46	0.55	0.55	0.67	0.62
MN	24.63	25	26.01	25.92	25.53	24.34	24.79	25.64	23.67	24.12	25.02
NP	16.36	14.76	14.94	17.2	15.27	13.99	13.56	14.49	13.48	15.24	14.67
NE	0.1	0.1	0.1	0.11	0.09	0.1	0.11	0.12	0.1	0.1	0.11
PA	20.52	19.55	19.95	20.43	20.29	19.47	19.5	19.59	18.83	18.51	19.42
SE	0.46	0.49	0.56	0.52	0.43	0.44	0.46	0.48	0.44	0.43	0.62
SP	6.82	6.56	6.78	6.2	6.72	6.12	5.56	7.37	6.08	7.36	6.89
Total	79.92	78.37	79.75	80.62	80.06	74.77	74.85	81.06	74.2	79.24	80.95

Note: AP = Appalachia, CB = Corn Belt, DL = Delta States, LA = Lake States, MN = Mountain States, NE = Northeast, NP = Northern Plains, PA = Pacific, SE = Southeast, and SP = Southern Plains.

Appendix table 24: Regional applied irrigation amounts under reference and climate change scenarios for 2060 (with fixed acreage allocation)

Applied irrigation water, million acre-feet, 2060											
Region	Reference	Average CC	CGCM _Low	CSIRO _Low	HADN _Low	CGCM _Mid	CSIRO _Mid	MIROC _Mid	CGCM _High	CSIRO _High	MIROC _High
AP	0.16	0.15	0.15	0.15	0.15	0.11	0.15	0.19	0.14	0.15	0.2
CB	1.64	1.49	1.51	1.38	1.55	1.17	1.49	1.56	1.42	1.54	1.82
DL	9.1	9.66	9.14	8.03	9.77	7.91	9.61	10.72	9.47	9.64	12.64
LA	0.69	0.56	0.57	0.56	0.57	0.58	0.51	0.58	0.52	0.54	0.64
MN	25.15	24.71	26.11	25.52	25.02	23.13	24.42	25.66	23.83	23.07	25.66
NP	18.51	15.22	16.19	17.81	16.97	13.44	14.95	14.97	13.1	14.13	15.39
NE	0.11	0.11	0.11	0.11	0.1	0.09	0.1	0.11	0.09	0.11	0.12
PA	20.91	18.8	20.11	19.28	19.6	18.35	18.84	18.42	18.08	17.63	18.89
SE	0.47	0.46	0.53	0.49	0.39	0.38	0.48	0.44	0.44	0.39	0.63
SP	7.51	6.81	6.86	6.65	7.24	6.27	6.01	7.75	6	7.17	7.34
Total	84.25	77.97	81.28	79.98	81.36	71.43	76.56	80.4	73.09	74.37	83.33

Note: AP = Appalachia, CB = Corn Belt, DL = Delta States, LA = Lake States, MN = Mountain States, NE = Northeast, NP = Northern Plains, PA = Pacific, SE = Southeast, and SP = Southern Plains.

Appendix table 25: Regional applied irrigation amounts under reference and climate change scenarios for 2080 (with fixed acreage allocation)

Applied irrigation water, million acre-feet, 2080											
Region	Reference	Average CC	CGCM _Low	CSIRO _Low	HADN _Low	CGCM _Mid	CSIRO _Mid	MIRO C_Mid	CGCM _High	CSIRO _High	MIROC _High
AP	0.16	0.15	0.15	0.15	0.14	0.11	0.13	0.19	0.12	0.15	0.2
CB	1.66	1.29	1.45	1.43	1.32	0.99	0.96	1.33	1.12	1.31	1.68
DL	9.18	8.75	9.06	8.36	9.01	7.12	6.87	9.5	8.43	8.47	11.94
LA	0.73	0.51	0.61	0.61	0.51	0.52	0.39	0.54	0.44	0.4	0.61
MN	25.71	23.97	26.65	25.27	24.6	23.47	22.94	24.68	21.72	21.73	24.65
NP	19.79	14.6	16.35	18.57	16.12	13.3	13.07	14.99	11.24	11.92	15.81
NE	0.12	0.1	0.1	0.11	0.09	0.09	0.11	0.11	0.08	0.09	0.12
PA	21.3	17.94	19.41	19.35	19.67	17.87	17.88	17.36	16.37	15.94	17.63
SE	0.47	0.42	0.47	0.51	0.37	0.37	0.37	0.41	0.36	0.32	0.61
SP	7.46	6.17	6.62	6.29	6.72	5.61	4.8	6.98	5.26	6.21	7.07
Total	86.58	73.9	80.87	80.65	78.55	69.45	67.52	76.09	65.14	66.54	80.32

Note: AP = Appalachia, CB = Corn Belt, DL = Delta States, LA = Lake States, MN = Mountain States, NE = Northeast, NP = Northern Plains, PA = Pacific, SE = Southeast, and SP = Southern Plains.