CLIMATE, WEATHER AND STRAWBERRIES

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Sociology Technical Report 1047 February 2017

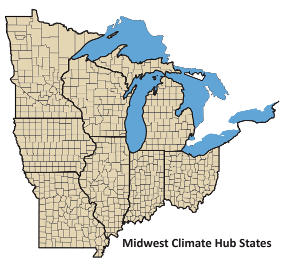
Climate, Weather and Strawberries

This document may be cited as:

Morton, Lois Wright, Natalia Peres, Clyde Fraisse, and Mark Gleason. 2017. Climate, Weather and Strawberries. Sociology Technical Report 1047. Department of Sociology, Iowa State University, Ames, Iowa. 16 pp.

This weather-based uncertainty and specialty crop production series presents conceptual maps of growers' views and priorities on apples (technical report 1046), wine grapes (technical report 1043), hops (technical report 1045), strawberries (technical report 1047) and sweet corn (technical report 1048). Department of Sociology, College of Agriculture and Life Sciences, Iowa State University, Ames Iowa. www.soc.iastate.edu/research/specialtycrops/

Report design and format by Renea Miller, Department of Sociology, Iowa State University, Ames, Iowa. February 2017. USDA Census of Agriculture data tables and figures by Anna Johnson. Special thanks to the Florida Strawberry Growers Association for hosting the grower meeting to gather these data.



This research, North Central Fruit, Vegetable and Wine Growers' Assessment of Soil and Water Vulnerability Under Changing Climate Conditions and Extreme Weather Events funded by USDA-Agricultural Research Service (ARS) Midwest Climate Hub.

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Florida strawberry production and a changing climate: growers' views and priorities to manage uncertainty in production systems

Lois Wright Morton, Natalia Peres, Clyde Fraisse, and Mark L. Gleason

Strawberry production, weather and climate risks

Strawberry production is sensitive to temperature, water availability, solar radiation, wind, air pollution, and carbon dioxide (CO_2). Abundant water is essential to achieve high quality berries and high yields. Some varieties of strawberries produced with water deficits have reduced leaf areas, poor root development and reduced berry size and yield (Walthall et al. 2012). However, too much water can also be problematic. Walthall et al. (2012) report severe flooding and saturated soils in recent years in Florida, Georgia and the East Coast. Strawberries acquire a "watery" flavor when grown in excess water due to lower sugar content. To address uncertainties in precipitation, strawberry growers must carefully manage water by irrigating their crop when it is dry and restricting water when possible to make berries sweeter. While moderate reductions in sunlight can improve yield and quality in some berry varieties, too much light and high temperature levels can lead to fruit bronzing, which damages the berry surface and reduces quality. Extreme heat can also affect strawberry production as was observed in Florida during the 2015-16 season. Warm day and night temperatures in December, 2015 affected flower induction and significantly reduced fruit yields. Weather patterns, including moderate temperatures and extended hours of leaf wetness following daily rainfall, can create a near perfect environment for the outbreak of strawberry diseases.

These are only a few of the weather-climate effects on production systems which strawberry growers must factor into their short and longer term management decisions. Walthall et al. (2012) suggest that climate is an additional risk joining production, finance and marketing risks already managed by growers. They note that climate risk will add complexity to United States (U.S.) specialty crop systems and increase uncertainty in agricultural decision environments. Changes in climate interact with other environmental and societal factors in ways that can either moderate or intensify its impacts on strawberry production systems. In conjunction with changes in the timing and distribution of precipitation, warmer growing season temperatures result in greater crop water requirements, with potential to affect yield and profits as a result (Melillo et al. 2012). Precipitation and temperature patterns as well as other weather and climate variables are specific to individual regions, sub-regions, and localities; thus, their impacts are localized also.

As climate and weather become more variable, strawberry growers face increased uncertainty in making decisions about their crop. One interpretation of this uncertainty is that growers may not have quite enough information to adequately evaluate their management options in the context of climate risk. Uncertainty can stem from social, economic, relational and/or biophysical factors that constrain or limit knowledge needed to make timely, good decisions. **What is not well understood is how strawberry growers perceive climate-weather risks to their production systems and what kind of adaptations have potential to reduce uncertainties associated with their management decisions.** This technical report is a preliminary effort to summarize information gathered from Florida strawberry growers to better understand what they are thinking and how they view uncertainty and their production challenges. First, a brief overview of U.S. and Florida strawberry production is presented, followed by the methodology used to gather and analyze grower information. Then, conceptual maps of Florida strawberry growers' views and priorities associated with managing their production systems under increasing uncertainties are shown and discussed. Supporting data are found in Appendices I and II.

Strawberry production in the United States

The United States (U.S.) produced three billion pounds of strawberries, valued at nearly $2.9 billion in 2014 (Figure 1). Strawberries are marketed year around with per person consumption of strawberries steadily increasing over the last 20 years. Climate plays a big role in where strawberries are grown. California has a favorable climate in the southern and coastal areas and produces over 90 percent of the U.S. strawberry crop almost 12 months of the year; other states produce primarily for fresh market between March and November (AgMRC 2015). According to the 2012 U.S. Census of Agriculture, there were 10,388 U.S. strawberry farms (Figure 2) representing 67,467 acres of strawberries (Figure 3) in 2012.

Florida strawberry production, weather and climate

Florida consistently ranks second in the U.S. in the production of strawberries behind California, producing between 10 and 15 percent of the total U.S. crop, and almost all of the domestically produced winter crop (Mossler 2012). Mild temperatures allow the production of strawberries in peninsular Florida during the winter season. Single crown (stem) strawberry plants are planted in Florida during the fall, from late September to early November. Flowering and fruit production generally begins in November and continues into March or April.

Most of Florida consists of a low elevation, 400-mile-long peninsula, which is part of the southeastern coastal plain that stretches from Texas to Virginia (Winsberg 2003). The climate of most of the state is classified as humid subtropical with hot summers according to the Köppen climate classification (Peel et al. 2007). Mean average temperatures during Florida's coldest month (January) range from the lower 50s (10°C-12°C) in the north to the high 60s (19°C-21°C) in the south (Figure 4). During the hottest month (July but in some places August) average temperatures are almost the same throughout the state ranging between 81°F to 83°F (27°C-28°C). Large water bodies such as the Atlantic Ocean and the Gulf of Mexico are major modifiers of the state's temperature during all seasons but particularly during the winter when temperatures in nearby locations remain milder than inland areas.

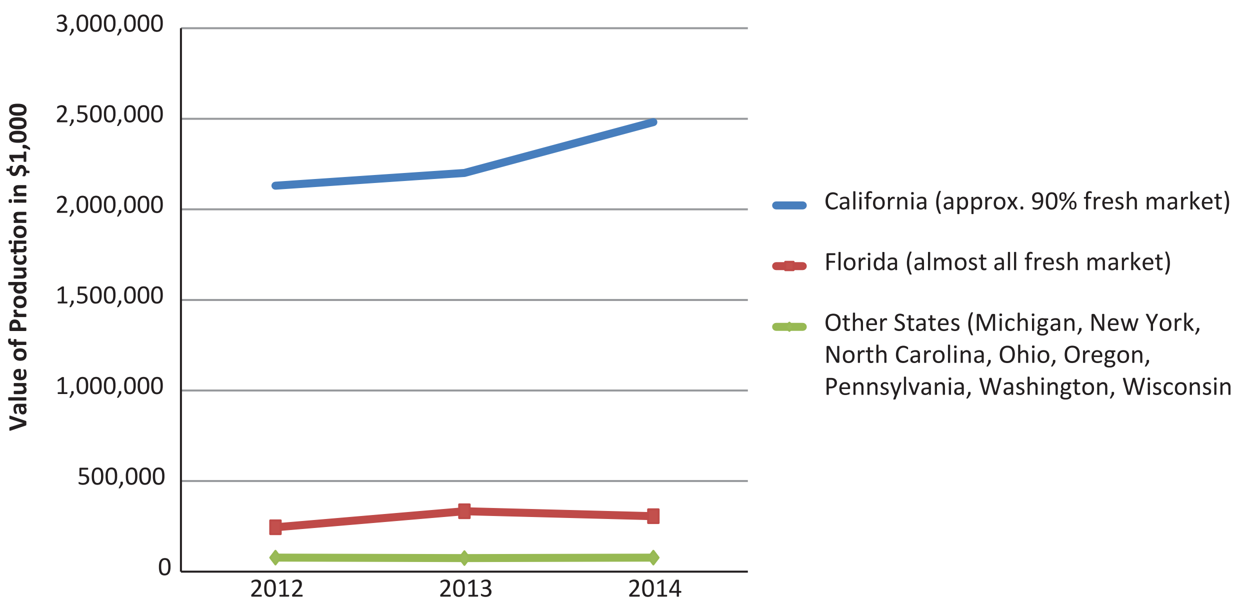


Figure 1. Total value of U.S. strawberry production from 2012-2014. Total value of 2014 U.S. crop $2,865,432,000; California 2014 crop value $2,481,496,000; and Florida 2014 crop value $306,508,000.

Noncitrus Fruits and Nuts 2014 Summary: Released July 17, 2015, National Agricultural Statistics Service (NASS), Agricultural Statistics Board, United States Department of Agriculture (USDA). Strawberry Area Planted, Harvested, Yield, Production, Price, and Value—States and United States: 2012-2014.

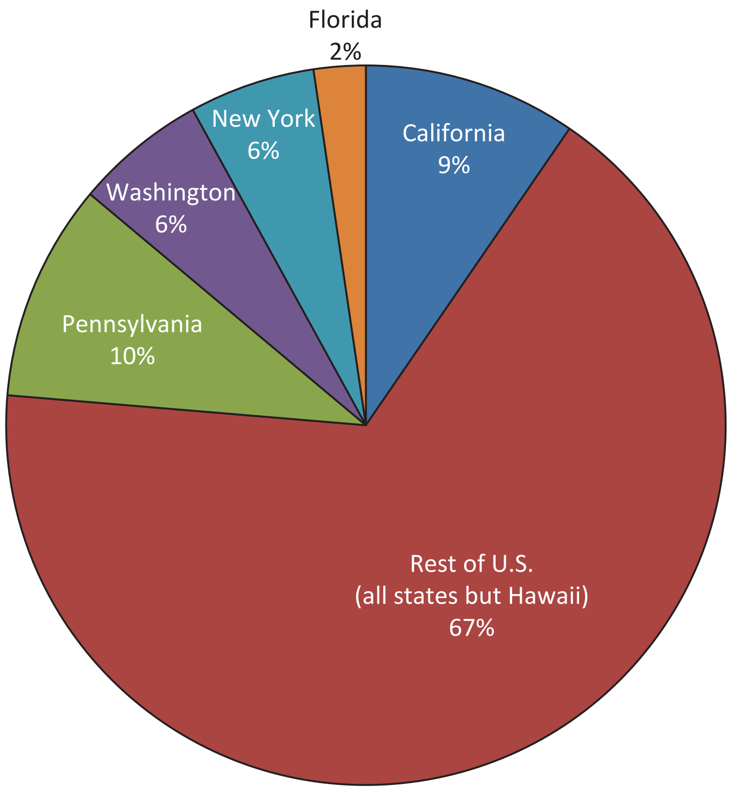


Figure 2. Number of U.S. farms in strawberry production, 10,388. USDA NASS (National Agricultural Statistics Service). U.S. Census of Agriculture. 2012.

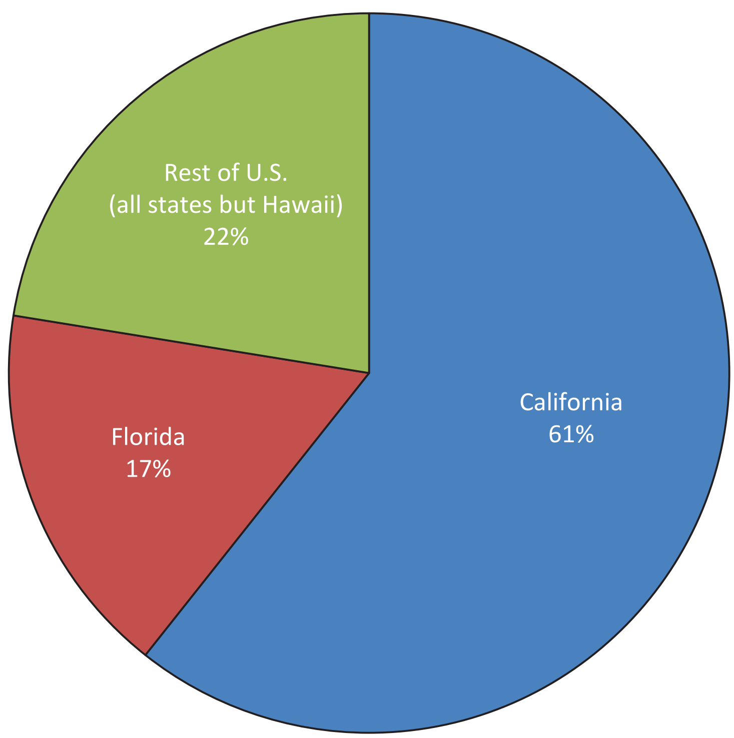


Figure 3. Total U.S. acres in strawberry production, 67,467 acres. U.S. Census of Agriculture. 2012.

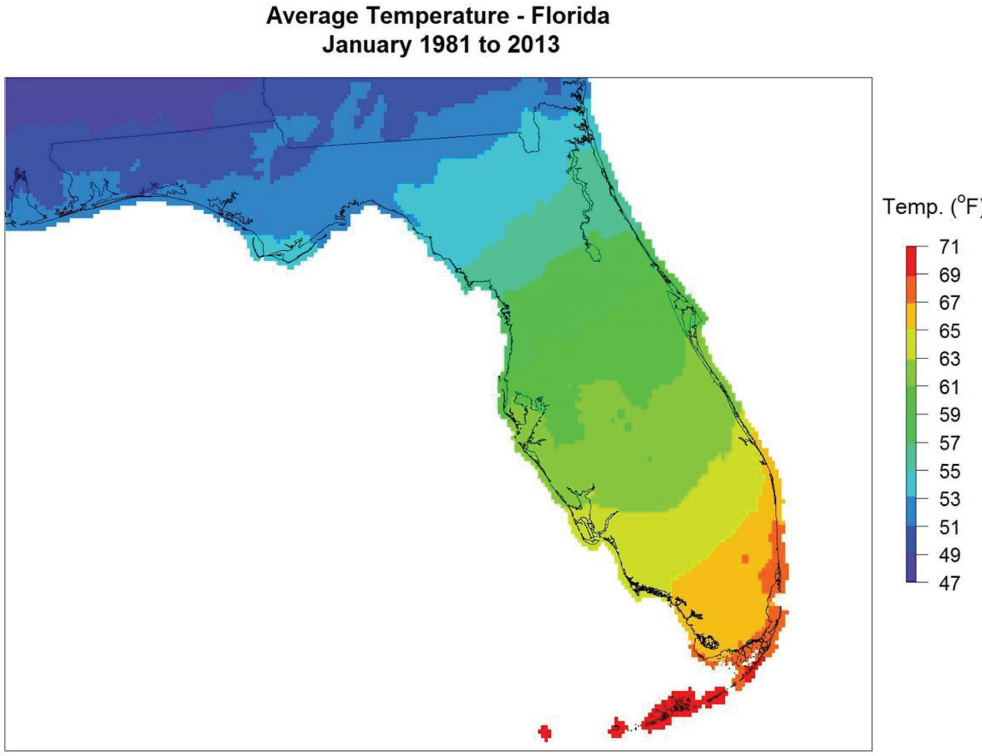


Figure 4. Average Florida temperature, January 1981-2013. AgroClimate group, University of Florida (Data source: PRISM Group, Oregon State University).

The weather in Florida plays a critical role in strawberry production. Disease and insect development are driven by temperature, rain, humidity and other environmental factors. Pest and disease management is a big part of strawberry production. Fungal diseases pose a special challenge for strawberry growers in humid and warm climates conducive for disease development, such as the climate in Florida. Anthracnose fruit rot (AFR), caused by *Colletotrichum acutatum,* and Botrytis fruit rot (BFR), caused by *Botrytis cinerea*, are the most important diseases for production of annual strawberries in Central Florida and worldwide. Anthracnose is a serious disease that affects the fruit in addition to flowers and petioles. It is favored by warm temperatures (>18°C) and wet weather. Losses due to the anthracnose can exceed 50% when conditions favor disease development, even in well-managed fields (Turechek et al. 2006). BFR is an important pre-harvest and postharvest disease of strawberry, infecting the floral parts, including stamens and petals. The conidia are wind—and splash dispersed, requiring free moisture (>4 h of leaf wetness) and cool temperatures (15°C-22°C) to infect and sporulate. A weather-based advisory system has been developed to advise growers on the need for fungicide sprays to control AFR and BFR (Strawberry Advisory System (SAS); http://www.agroclimate.org/tools/strawberry/). Models in the system are based on temperature and leaf wetness duration and email and/or text alerts are sent to growers when conditions are favorable for disease development and fungicide sprays are needed. Monitoring weather conditions and following SAS recommendations has helped Florida strawberry growers control these diseases with a reduced number of fungicide applications.

Concept mapping views and priorities

Strawberry growers are seeking strategies to better assess the risks and vulnerabilities, and reduce uncertainty in their production systems under changing short- and long-term weather conditions and improve their decision-making capacities. Eleven Florida strawberry growers and crop advisors were identified in Spring 2016 as key leaders in their industry and were invited to meet in Dover, Florida at the Strawberry Growers Association headquarters to discuss impacts of temperature, precipitation, and other weather-related issues on their production systems. The focus was on critical production and marketing decision points throughout the year for the strawberry crop. Scientists from University of Florida and Iowa State University met with the growers to identify and prioritize production concerns and uncertainties in their systems that they have difficulty managing. A concept mapping process was used to capture individual growers' challenges as well as areas of common concern among the group. Of interest to the science team was to gather information to guide future research and extension-outreach programming that would reduce uncertainty in different aspects of production decisions.

The concept mapping methodology is a participatory planning process that spatially maps the thoughts and knowledge of a particular group of people and enables the creation of a common framework for planning and evaluation of issues that matter to that group (Kane and Trochim 2007). The process begins with the group brainstorming key ideas together, then individually rating each of the idea statements by how critical or important it is to them, followed by individual conceptual sorting of the statements into groups of similar concepts.

On April 6, 2016, Florida strawberry growers first brainstormed by completing the statement: "One uncertainty in my production system I have difficulty managing is…" The brainstormed statements were recorded on a large screen where the entire group could read them and discuss as the list was made. Thirty-four statements were generated (see Appendix II for the list of 34 statements). Then, 11 participants individually rated each statement using a 1-5 Likert scale based on how critical they thought it was to reduce uncertainty in their production system related to this statement (1 = not critical; 2 = somewhat critical; 3 = moderately critical; 4 = very critical; 5 = extremely critical). Lastly, participants individually sorted the 34 statements into separate piles or groups based on perceptions of statement similarities and gave them labels. Some participants lumped statements together, whereas others split the statements into many groupings. The smallest number of groups created by a participant was four; the largest contained nine groupings.

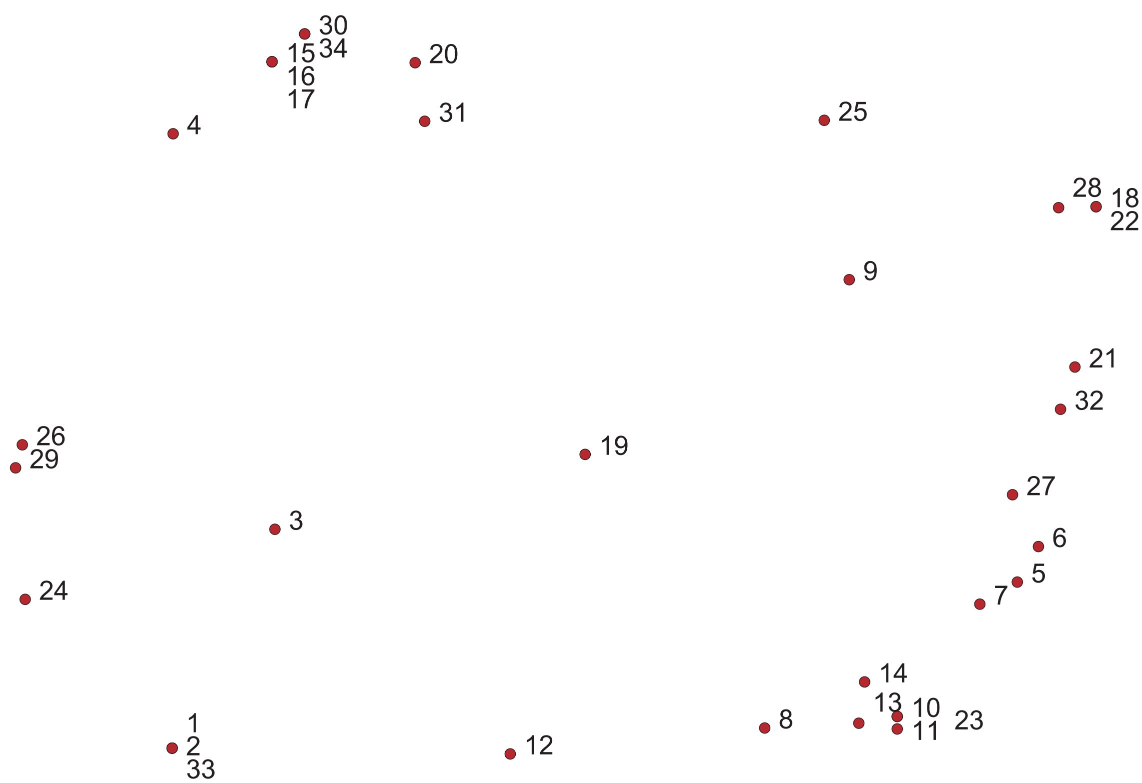
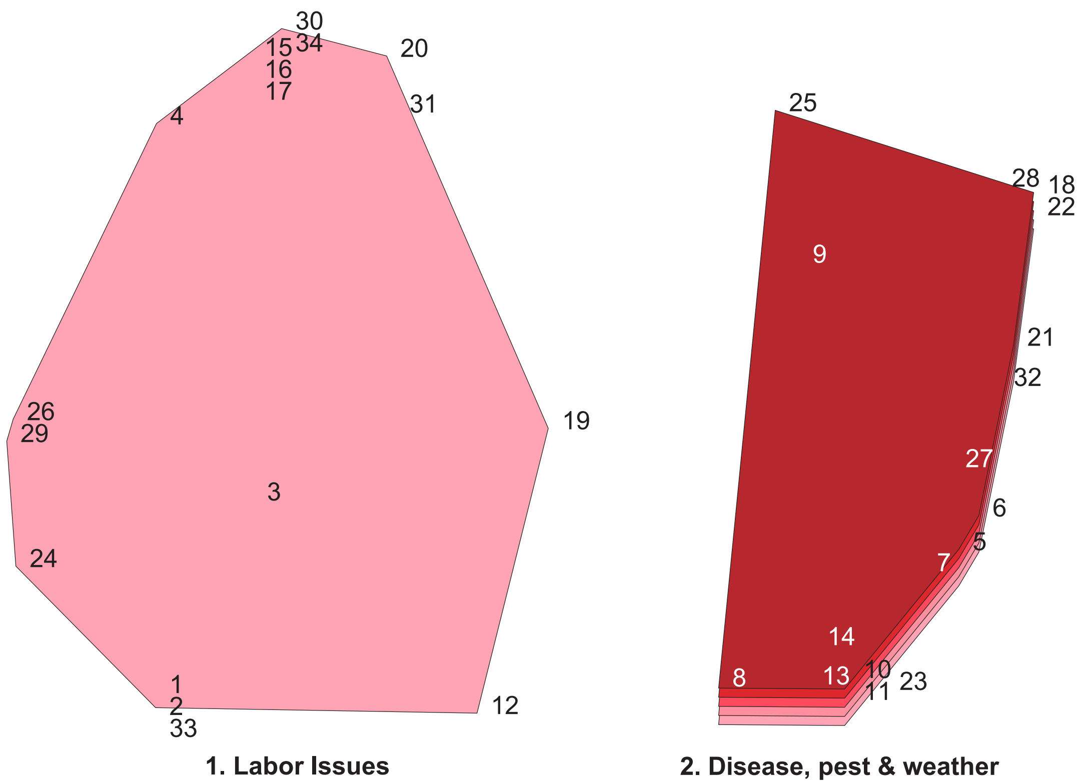


Figure 5. Point map of Florida strawberry growers' sort of 34 statements, "One uncertainty in my production system I have difficulty managing is…"

Conceptual maps were computed using multi-dimensional scaling analysis that locates each statement as a separate point on a map based on how the participants sorted the 34 statements. A similarity matrix from the sorts was constructed from statements based on how they were grouped together by the participants. Statements that were conceptually viewed as similar are located closer to each other on the point map and those that were grouped together less frequently, have more distance separating them on the map (Figure 5). Hierarchical cluster analysis was used to partition the statements on the map into clusters representing conceptual groupings. Then the average ratings for each statement and each cluster, based on how critical it is to reduce uncertainty, were computed and overlaid on the spatial map.

Florida strawberry growers' conceptual maps and priority ratings

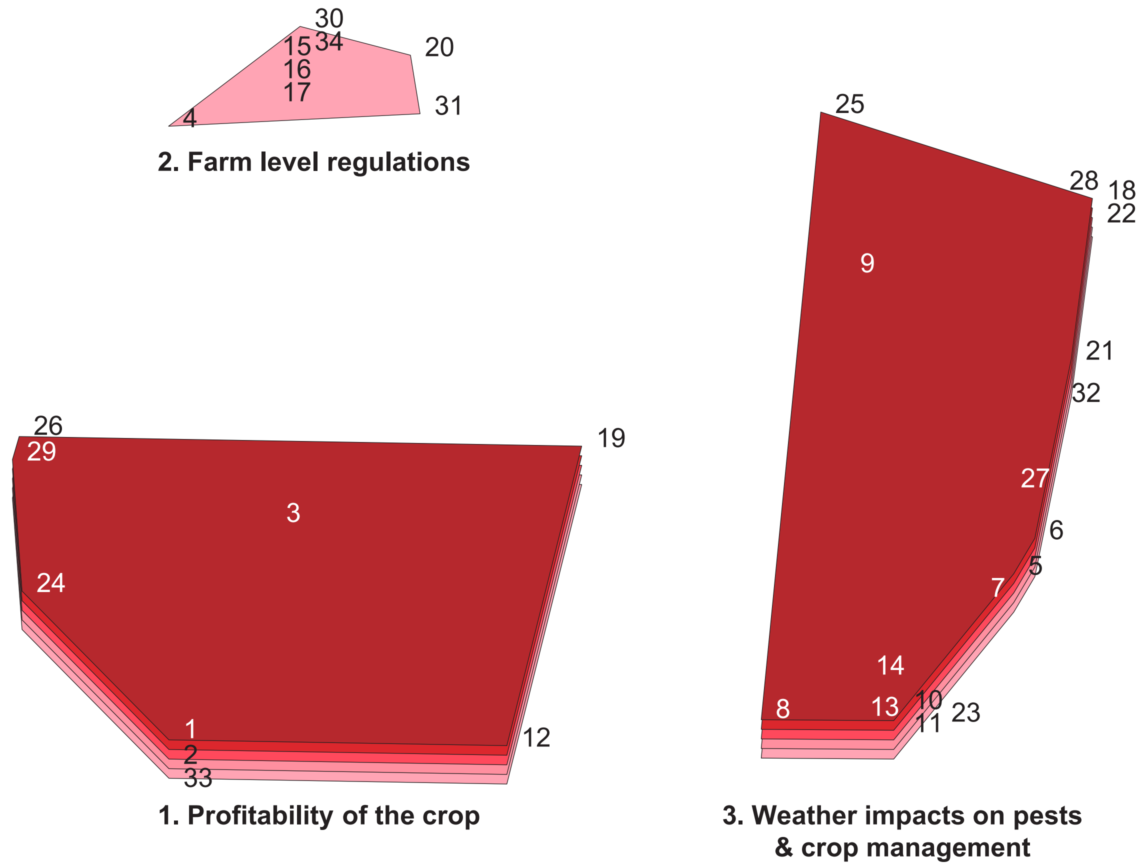
The point map (Figure 5) and cluster maps represented by the polygons in Figures 6 and 7 offer a visual way to understand the conceptual thinking of the strawberry grower participants. The maps along with the cluster lists (Table 1; Appendix I) and statement ratings list (Table 2; Appendix II) provide data that help interpret what growers view as critical uncertainties in



Cluster Legend

Layer	Value
1	3.67 to 3.68
2	3.68 to 3.70
3	3.70 to 3.71
4	3.71 to 3.72
5	3.72 to 3.73

Figure 6. Two-cluster strawberry growers' conceptual map derived from the prompt, "One uncertainty in my production system I have difficulty managing is…" and rated based on, "How critical is it to reduce levels of uncertainty in your production system related to this statement to make better decisions? (1 = not critical; 2 = somewhat critical; 3 = moderately critical; 4 = very critical; 5 = extremely critical)."



Cluster Legend

Layer	Value
1	3.60 to 3.63
2	3.63 to 3.66
3	3.66 to 3.68
4	3.68 to 3.71
5	3.71 to 3.74

Figure 7. Three-cluster Florida strawberry growers' conceptual map derived from the prompt, "One uncertainty in my production system I have difficulty managing is…" and rated based on, "How critical is it to reduce levels of uncertainty in your production system related to this statement to make better decisions? (1 = not critical; 2 = somewhat critical; 3 = moderately critical; 4 = very critical; 5 = extremely critical)."

Table 1. Florida strawberry growers' priority ratings of uncertainties in their production systems. "One uncertainty in my production system I have difficulty managing is…"

Cluster Name	Grand Mean	# Statements	Top-ranked Statement	Statement Rating
Profitability of the crop	3.74	9	3. Labor scarcity; unstable labor supply	4.55
Weather impacts on pest & crop management	3.73	17	9. Quality control of nursery plants	4.82
Farm level regulations	3.60	8	16. Proliferation of regulations imposes increasing burden on growing operations & growers	4.27

their production systems and which uncertainties are more difficult for them to manage. These three maps—the point map and two different cluster maps—are different ways of portraying the conceptual structure of the data. However, the maps are inter-related and reflect different ways to assess what strawberry growers are thinking. The point map (Figure 5) represents an integration of where all participants located each statement in relationship to other statements—i.e. the way statements were categorized as similar or different. Each of the 34 different statements growers brainstormed are uniquely located on the point map. Note some numbers group together and other numbers are quite distant from other numbers. Thus, even without drawing polygons around the grouped numbers, it is apparent that the statement numbers group into two or more distinct clusters.

Florida cluster maps and priority ratings

The two-cluster (Figure 6) and three-cluster (Figure 7) rating maps show how the statements can be grouped with average cluster ratings overlaid. The cluster names were chosen subjectively by the researchers using a combination of the labels given by growers and the items within each clusters. Multi-layered polygons represent the relative importance of the different clusters. For example, the five layers of cluster 2 (*Disease, pest & weather*) in Figure 6 indicate that a number of items in that cluster were rated as very critical by most of the participants.

The two-cluster rating map in Figure 6 shows two major conceptual areas of uncertainty identified by the strawberry growers: *Labor issues* and *Disease, pest & weather*. Although the *Disease, pest & weather* polygon has the higher priority weighting (3.67-3.73) compared to *Labor issues* (3.67-3.68) as critical to reduce uncertainty, it is important to note that the value range for both of these clusters is very narrow representing an average assessment of very critical. This is not unexpected; growers were asked to identify areas of uncertainty and all items brainstormed by the group are substantive challenges they are facing. This two-cluster map reflects that uncertainties associated with strawberry production are both social and biophysical in nature.

One value of the conceptual maps is that they identify and prioritize general and specific areas where research and programming would most benefit growers and guide where to invest resources. Further analysis of the point map reveals that the *Labor issues* and *Disease, pest & weather* uncertainties can be more finely divided into smaller, more focused sub-areas for improved targeting. Figure 7 shows a three-cluster map that breaks the labor issues polygon from Figure 6 into two sub-areas of uncertainty: *1) Profitability of the crop*, and *2) Farm level regulations*. The *Disease, pest & weather* polygon does not change shape but has been relabeled, *Weather impacts on pests and crop management*, to better reflect the statements within the cluster. Table 1 provides summary data on these three clusters, their grand means and the top-ranked statements in each cluster. Note that all three clusters have grand means that are very similar (3.74, 3.73, 3.60), falling just below very critical (4.0) but well above moderately critical (3.0) to reduce levels of uncertainty.

A look at the statements within each of the three clusters (Figure 7; Table 1) offers a deeper understanding of what each cluster conceptually represents (Appendix I).

Profitability of the crop, consisting of 9 statements, is the highest rated cluster (3.74), with growers giving it an overall value of slightly below very critical (4.0) but considerably above moderately critical (3.0) to reduce uncertainty. The top ranked statement in this cluster, labor supply scarcity; unstable labor supply with a mean of 4.55 is considered very-to-extremely critical to reduce uncertainty. Two other statements rated above 4.0, very critical to reduce uncertainty are competition with Mexico (4.18) and volatile prices for strawberries (4.09) (Appendix I). Costs and prices are the major theme throughout this cluster, with supply costs rising rapidly (3.91), price does not always reflect supply (3.91), and increasing uncertainty of financing growing operations (3.82) rated as very critical. Two statements are rated moderately critical, optimizing plant fertility (3.36) and high capital cost of entry into growing strawberries precludes involvement by younger people (3.18). The last statement, winter weather in northern states impairs orders and delivery of strawberries (2.64), is rated below moderately critical but well above somewhat critical (2.0).

Weather impacts on pest & crop management, the second highest ranked cluster, consists of 17 statements ranging from a high of 4.82

(extremely critical to reduce uncertainty) to 2.73 (moderately critical to reduce uncertainty). The grand mean for this cluster at 3.73 has a rating almost identical to the profitability of the crop cluster, and can be interpreted as very critical to reduce uncertainty. The top ranked statement for this cluster, quality control of nursey plants, is rated extremely critical at 4.82. Also rated extremely critical to reduce uncertainty are two additional statements, obtaining nursery plants that are disease (anthracnose) and pest (spider mites) free (4.64) and increasing incidence of resistance to pesticides (4.55) (Appendix I). The next two statements rated very critical are related to pesticide issues, current pesticides have lower efficacy than past pesticides (4.09) and disappearance of methyl bromide has compromised efficacy of pest and disease control (4.09). Five statements which are also very critical but fell just below 4.0 link weather to production concerns: increasing rate of introduction of invasive insect pests and diseases (3.91): unseasonable weather extremes (heat, cold, rain) delay fruiting and harvest resulting in missing the most profitable market period (3.82); weather strongly impacts disease and insect control (3.82); lack of information about timing of rainfall can impair timeliness of harvest (3.73); and freezes can cause severe loss of early production (3.64). Five statements rated moderately critical (3.0) continue to elaborate the weather risks that affect production: rain and humidity increase disease outbreak risk (3.45); uncertainty of which major disease problems will predominate in a given season (3.36); excessive heat increases pressure from insect pests (3.36); weather uncertainty impacts planning for labor needs during harvest, especially for guest workers (90-day advance arrangement for H2A workers) (3.27); and lack of accurate long-range forecasts (6-7 months) impairs optimal selection of varieties (3.18). The last two statements in this cluster fall just below 3.0 (moderately critical): damage to fruit by migrating birds (robins, cedar waxwings) (2.91) and hurricanes and tropical storm track forecasts impact timing of field preparation (fumigation and soil preparation) (2.73).

Farm level regulations, the third highest rated cluster (3.60) is a societal influence sub-category. This cluster has eight statements with the highest ranked statement, proliferation of regulations imposes increasing burden on growing operations and growers at 4.27 (very critical to reduce uncertainty). The second highest rated statement in this cluster is increasing pollinator-protection regulations (4.09). This is followed by two other "very critical to reduce uncertainty statements", increasingly burdensome and unpredictable regulations add to record-keeping requirements (3.91) and overlapping regulations from

Table 2. Top quartile (25%) strawberry growers' ranked statements. "How critical is it to reduce levels of uncertainty in your production system related to this statement to make better decisions? (1 = not critical; 2 = somewhat critical; 3 = moderately critical; 4 = very critical; 5 = extremely critical)."

Statement Number		Average Rating	Cluster Number
9	Quality control of nursery plants	4.82	3
28	Obtaining nursery plants that are disease (anthracnose) and insect-free (spider mites)	4.64	3
3	Labor scarcity, unstable labor supply	4.55	1
18	Increasing incidence of resistance to pesticides.	4.55	3
16	Proliferation of regulations imposes increasing burden on growing operations and growers.	4.27	2
33	Competition with Mexico	4.18	1
1	Marketing, volatile prices for strawberries	4.09	1
20	Increasing pollinator-protection regulations.	4.09	2
22	Current pesticides have lower efficacy than past pesticides.	4.09	3
25	Disappearance of methyl bromide compromised efficacy of pest and disease control.	4.09	3

multiple government agencies with conflicting interpretation (3.64). Three statements rated just above moderately critical (3.0) are government labor-related programs have limited impacts (3.36); difficulty in obtaining sufficient water use permits (3.36); and difficulty in renewal of water use permits (3.27). The final statement in this cluster, also water related, is irrigation water quality and runoff restrictions at 2.91 (moderately critical).

Top quartile statements. Another way to examine the findings is to list all 34 statements arranged by highest to lowest rating (Appendix II). The top quartile (25%) of strawberry growers' statement rankings based on ratings is shown in Table 2. These top 10 statements range from 4.82, extremely critical to 4.09, very critical that levels of uncertainty be reduced in strawberry production systems to make timely, good decisions. These highest rated statements focus on pest and disease management, capacity to be price competitive, and dealing with the burden of regulations.

Observations

Emerging and unknown risks associated with increasingly variable local and regional weather are reverberating throughout U.S. agriculture. Strawberries are biennial crops that are highly sensitive to temperature (frost and excessive heat), prolonged periods of wetness or drought, high winds, hail, and long-term shifts in climate. The increasing uncertainty about weather impacts on pest and crop management is one of specialty crop growers' largest challenges. Uncertainties are associated with water availability, disease and pest risk, cultivar selection, timing of planting and harvest, and the new risks that are projected to occur as the earth's climate changes (Adger et al. 2009).

Increased climate variability in Florida will pose new challenges to strawberry growers. Warmer winters may reduce the chill accumulation required for homogeneous flowering and adequate fruit set and yield, water availability for irrigation and frost control may be reduced due to the competition with urban demands, and environmental conditions may become more favorable for certain diseases and pests.

Grower operations now and in the future are affected by an increasingly variable climate, suggesting a need for research, decision support tools and information that help them address risk and uncertainty and inform adjustments to their management. This preliminary report offers a snapshot of Florida strawberry growers' observations, thoughts, concerns, and priorities for their crop. The concept mapping process identified profitability of the crop and weather impacts on pest and crop management as their top concerns. Despite serious challenges, the future of the Florida strawberry industry is bright. Many of the uncertainties, such as regulation and production in other areas that are faced by growers are beyond their direct control. The primary means that growers have at their disposal is reduction of production costs. If that can be accomplished, they can compete successfully by producing a high quality product. Models to forecast weather and disease and pest severity will reduce pesticide applications and make them more effective. Forecasting crop production will allow growers to better plan the needs for labor and assist with marketing.

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Appendix I. Florida strawberry growers' three-cluster rankings

Florida strawberry grower statements sorted by cluster derived from the prompt, "One uncertainty in my production system I have difficulty managing is…" and rated based on, "How critical is it to reduce levels of uncertainty in your production system related to this statement to make better decisions? (1 = not critical; 2 = somewhat critical; 3 = moderately critical; 4 = very critical; 5 = extremely critical)."

One uncertainty in my production system I have difficulty managing is…

		Average Rating
1. Profitability of the crop		**3.74**
3	Labor, scarcity, unstable labor supply	4.55
33	Competition with Mexico	4.18
1	Marketing, volatile prices for strawberries	4.09
24	Supply costs rising rapidly	3.91
2	Price does not always reflect supply	3.91
26	Increasing uncertainty of financing growing operations	3.82
19	Optimizing plant fertility	3.36
29	High capital cost of entry into growing strawberries precludes involvement by younger people	3.18
12	Winter weather in northern states impairs orders and delivery of strawberries	2.64

Count	Std. Dev.	Variance	Min.	Max.	Avg.	Median
9	0.55	0.30	2.64	4.55	3.74	3.90

		Average Rating
2. Farm level regulations		**3.60**
16	Proliferation of regulations imposes increasing burden on growing operations and growers	4.27
20	Increasing pollinator-protection regulations	4.09
17	Increasingly burdensome and unpredictable regulations add to record-keeping requirements	3.91
15	Overlapping regulations from multiple government agencies with conflicting interpretations	3.64
4	Government labor-related programs have limited impact	3.36
30	Difficulty in obtaining sufficient water use permits	3.36
34	Difficulty in renewal of water use permits.	3.27
31	Irrigation water quality and runoff restrictions	2.91

Count	Std. Dev.	Variance	Min.	Max.	Avg.	Median
8	0.43	0.19	2.91	4.27	3.60	3.50

One uncertainty in my production system I have difficulty managing is…

		Average Rating
3. Weather impacts on pest & crop management		**3.73**
9	Quality control of nursery plants	4.82
28	Obtaining nursery plants that are disease- (anthracnose) and insect-free (spider mites)	4.64
18	Increasing incidence of resistance to pesticides	4.55
22	Current pesticides have lower efficacy than past pesticides	4.09
25	Disappearance of methyl bromide compromised efficacy of pest and disease control	4.09
21	Increasing rate of introduction of invasive insect pests and diseases	3.91
8	Unseasonable weather extremes (heat, cold, rain) delay fruiting & harvest; & miss most profitable market	3.82
5	Weather strongly impacts disease and insect control	3.82
11	Lack of information about timing of rainfall can impair timeliness of harvest	3.73
10	Freezes can cause severe loss of early production	3.64
7	Rain and humidity increase disease outbreak risk	3.45
27	Uncertainty of which major disease problems will predominate in a given season	3.36
6	Excessive heat increases pressure by insect pests	3.36
23	Weather uncertainty impacts planning for labor needs during harvest, especially for guest workers. (90-day advance arrangement for H2A workers)	3.27
13	Lack of accurate long-range forecasts (6 to 7 months) impairs optimal selection of varieties	3.18
32	Damage to fruit by migrating birds (robins, cedar waxwings)	2.91
14	Hurricanes and tropical storm track forecasts impact timing of field preparation (fumigation and soil preparation)	2.73

Count	Std. Dev.	Variance	Min.	Max.	Avg.	Median
17	0.57	0.32	2.73	4.82	3.73	3.70

Appendix II. Florida strawberry growers' ranked statements

Florida strawberry grower statements sorted by rating (high to low) derived from the prompt, "One uncertainty in my production system I have difficulty managing is…" and rated based on, "How critical is it to reduce levels of uncertainty in your production system related to this statement to make better decisions? (1 = not critical; 2 = somewhat critical; 3 = moderately critical; 4 = very critical; 5 = extremely critical)."

One uncertainty in my production system I have difficulty managing is…

Statement Number		Average Rating	Cluster Number
9	Quality control of nursery plants	4.82	3
28	Obtaining nursery plants that are disease- (anthracnose)and insect-free (spider mites)	4.64	3
3	Labor, scarcity, unstable labor supply	4.55	1
18	Increasing incidence of resistance to pesticides	4.55	3
16	Proliferation of regulations imposes increasing burden on growing operations and growers	4.27	2
33	Competition with Mexico	4.18	1
1	Marketing, volatile prices for strawberries	4.09	1
20	Increasing pollinator-protection regulations	4.09	2
22	Current pesticides have lower efficacy than past pesticides	4.09	3
25	Disappearance of methyl bromide compromised efficacy of pest and disease control	4.09	3
24	Supply costs rising rapidly	3.91	1
2	Price does not always reflect supply	3.91	1
17	Increasingly burdensome and unpredictable regulations add to record-keeping requirements	3.91	2
21	Increasing rate of introduction of invasive insect pests and diseases	3.91	3
26	Increasing uncertainty of financing growing operations.	3.82	1
8	Unseasonable weather extremes (heat, cold, rain) delay fruiting & harvest; & miss most profitable market	3.82	3
5	Weather strongly impacts disease and insect control	3.82	3
11	Lack of information about timing of rainfall can impair timeliness of harvest	3.73	3
15	Overlapping regulations from multiple government agencies with conflicting interpretations	3.64	2
10	Freezes can cause severe loss of early production	3.64	3
7	Rain and humidity increase disease outbreak risk	3.45	3
19	Optimizing plant fertility	3.36	1
4	Government labor-related programs have limited impact	3.36	2
30	Difficulty in obtaining sufficient water use permits	3.36	2
27	Uncertainty of which major disease problems will predominate in a given season	3.36	3
6	Excessive heat increases pressure by insect pests	3.36	3
34	Difficulty in renewal of water use permits	3.27	2

One uncertainty in my production system I have difficulty managing is…

Statement Number		Average Rating	Cluster Number
23	Weather uncertainty impacts planning for labor needs during harvest, especially for guest workers. (90-day advance arrangement for H2A workers)	3.27	3
29	High capital cost of entry into growing strawberries precludes involvement by younger people.	3.18	1
13	Lack of accurate long-range forecasts (6 to 7 months) impairs optimal selection of varieties	3.18	3
31	Irrigation water quality and runoff restrictions	2.91	2
32	Damage to fruit by migrating birds (robins, cedar waxwings)	2.91	3
14	Hurricanes and tropical storm track forecasts impact timing of field preparation (fumigation and soil preparation)	2.73	3
12	Winter weather in northern states impairs orders and delivery of strawberries	2.64	1