JOINT STATE AGENCY PUBLIC MEETING OF THE
ENVIRONMENTAL FARMING ACT SCIENCE ADVISORY PANEL (EFA SAP)
CALRECYCLE AND THE CALIFORNIA DEPARTMENT OF FOOD AND AGRICULTURE

MEETING AGENDA

January 15, 2016
9 AM to 4 PM
California Department of Food and Agriculture
Auditorium
1220 N Street
Sacramento, CA 95814
916-654-0433

LIVE STREAMING VIDEO

Please note that this is video streaming only.
For public comment and questions, please attend in person.
https://www.cdfa.ca.gov/LiveMediaStream.html

EFA SAP MEMBERSHIP

Don Cameron, Member and Chair
David Bunn, Resources Agency, Member
Jocelyn Bridson, MSc, Member
CalEPA, Vacant
Jeff Dlott, PhD, Member
Luana Kiger, MSc, Subject Matter Expert
Doug Parker, PhD, Subject Matter Expert

1. Introductions	Chair Cameron
2. Updates	
• Minutes from previous meeting	Chair Cameron
• SWEEP	Amrith Gunasekara
3. Agronomic use rates for compost application to support a CDFA incentive program on Healthy Soils	
• Background information	Amrith Gunasekara
• Agronomic compost application rates proposed by the expert subcommittee of the Science Panel	Kelly Gravuer
5. Public Comments	Chair Cameron
6. Future action items	Chair Cameron
7. Next meeting and location	Chair Cameron

Amrith (Ami) Gunasekara, PhD, CDFA Liaison to the Science Panel

All meeting facilities are accessible to persons with disabilities. If you require reasonable accommodation as defined by the American with Disabilities Act, or if you have questions regarding this public meeting, please contact Amrith Gunasekara at (916) 654-0433.
More information at: http://cdfa.ca.gov/Meetings.html and http://www.cdfa.ca.gov/EnvironmentalStewardship/Meetings_Presentations.html

CALIFORNIA DEPARTMENT OF FOOD AND AGRICULTURE (CDFA)
ENVIORNMENTAL FARMING ACT SCIENCE ADVISORY PANEL

Byron Sher Auditorium
California Environmental Protection Agency
1001 I Street
Sacramento, CA 95814

July 17, 2015

MEETING MINUTES

Panel Members

Don Cameron, Member and Chair
Mike Tollstrup, Member
Jeff Dlott, PhD., Member
Bruce Gwynne (Alternate), Natural Resources Agency

Subject Matter Experts

Doug Parker, PhD., Subject Matter Expert
Luana Kiger, MSC, Subject Matter Expert

State Agency Staff

Amrith Gunasekara, PhD. (CDFA)
Jenny Lester Moffitt, Deputy Secretary (CDFA)
Evan Johnson (CalRecycle)
Carolyn Cook (CDFA)

AGENDA ITEM 1

The meeting was called to order at 10:10 AM by the Chair, Mr. Don Cameron. Panel Chairman Mr. Cameron introduced the Healthy Soils Initiative (HSI) as an issue of relevance to all farmers. Introductions were made. Members present at the meeting include Mr. Cameron, Dr. Dlott, Mr. Tollstrup, and Mr. Gwynne (alternate for Dr. Bunn from Natural Resources Agency). A quorum was established.

AGENDA ITEM 2
Welcome Address- CalRecycle Deputy Director, Howard Levenson and CDFA Deputy Secretary Jenny Lester Moffitt

Deputy Secretary Moffitt welcomed the panel and audience to the meeting and provided background information on the Healthy Soils Initiative. CDFA was charged with leading the Healthy Soils Initiative as described in the Governors January 2014-15 budget

proposal and under the authority of the Environmental Farming Act of 1995. Dr. Levenson welcomed the group on behalf of EPA and Cal Recycle.

AGENDA ITEM 3
PREVIOUS MEETING MINUTES

CDFA staff presented the minutes from the previous May 14, 2015 meeting. The motion was made to accept the minutes as presented by Mr. Tollstrup, and seconded by Mr. Gwynne. The motion was moved by all members present and was accepted without further changes.

STATE WATER EFFICIENCY AND ENHANCEMENT PROGRAM (SWEEP)

Dr. Gunasekara provided an update on the State Water Efficiency and Enhancement Program (SWEEP). $10 million are available through the current fiscal year for grants to farmers to install irrigation systems that reduce water use and reduce greenhouse gas emissions. The application period closed on June 29, 2015. 345 applications were received, totaling $30.3 million in requests. The program was oversubscribed by 300%. A technical review period of the application had begun. Dr. Gunasekara noted that he would continue to update the Science Panel members at each meeting on SWEEP since the program continues to receive funding.

VACANT POSITION ON EFA SAP

Dr. David Bunn, Director of the Department of Conservation, has been appointed to serve on the EFA SAP from the Natural Resources Agency. Bruce Gwynne was filling in for Dr. Bunn at this meeting.

AGENDA ITEM 4 – HEALTHY SOILS INITIATIVE

A. IMPACT OF SOIL ORGANIC MATTER ON NUTRIEINT CONSERVATIO AND SOIL HEALTH – DR. WILLIAM HORWATH

Dr. Horwath provided an overview of soils, soil organic matter (SOM) and its role in soil health. Dr. Horwath also discussed the microbial environment and its contribution to building SOM. He also discussed the abiotic contribution to building SOM such as climate and moisture. His presentation included a case study and research studies which attempted to build SOM. Dr. Horwath facilitated questions from the Science Panel members and the public following his presentation.

MICROBIAL COMMUNITIES, COMPOST AND IMPLICATIONS FOR SOIL HEALTH – DR. GARY ANDERSEN

Dr. Gary Anderson of U.C. Berkeley presented on thermophilic aerobic decomposition (composting) and discussed some benefits of compost to soil health. Dr. Anderson's

research team has been studying which microbes are active in compost production. They are using microchip technology to detect different bacteria and archaea and understand how the different microbial species play different roles in the compost process and who dominants when and at what stages of the composting cycle. Dr. Anderson answered questions from the Science Panel members and the public following his presentation.

CALRECYCLE EFFORTS TO DATE ON COMPOST – DR. HOWARD LEVENSEN

Dr. Howard Levenson of CalRecycle provided an update on current policies and progress on promoting composting in California. He noted that California has policy drivers for increasing composting, including a statewide goal of 75% of solid waste diverted from landfills by 2020. Since organic waste makes up one-third of solid waste, composting will be a critical component of meeting that goal. Dr. Levenson noted that CalRecycle is engaged on several research initiatives on compost and suggested future research needs. Dr. Levenson answered questions from the Science Panel members and the public following his presentation.

A TOOL FOR INCENTIVIZING SOIL HEALTH IN AGRICULTURE (COMET-PLANNER) – DR. ADAM CHAMBERS

Dr. Adam Chambers provided an overview of a new tool (Comet-Planner) developed to quantify the GHG benefits of various farm management practices. Dr. Chambers showed how to use the tool and find background information and quantification methodology for each practice. He noted that soil health is an important priority and there is the goal of 111-124 $MMTCO_2e$ reduction by 2025. USDA NRCS used historical accomplishments in soil health through EQIP since 1997 to extrapolate what can be accomplished by 2025. Dr. Chambers facilitated questions from the Science Panel and the public following his presentation.

PUBLIC COMMENT AND DISCUSSION

Daniel Morash, California Safe Soil: They are exploring California aerobic enzymatic digestion. Additionally, unless we can prove the value of these products to farmers then projects won't be successful. Need research to back up and prove benefits to farmers.

Niles Brinton, Char Born: Commented that he was encouraged by the initiative. He suggested that the addition of biochar to compost can reduce off-gassing of ammonia and methane. The finished compost product also has a higher nitrogen content, possibly leading to less fertilizer demand. Biochar is a needed solution for dealing with woody biomass waste (ex; forest).

Pablo Garza, Nature Conservancy: Excited regarding the Healthy Soils Initiative and potential incentives for landowners, but also concerned about application of compost on

rangelands because it can lead to a decline in biological diversity. Requested that rangelands are discussed in the subcommittee on compost application rates.

Calla Rose Ostrander, Rathmann family foundation: Has maps and materials to share with the panel on various waste sources. Wants to promote a systems approach and management of organics in a way that protects air and water quality and gets organics back on land.

Cole Smith, UC Cooperative Extension: Inquired on the next steps in education and outreach. Hard to organize and disperse scientific information to the public.
Dr. Gunasekara responded that CalRecycle and CDFA can reach out to UC Extension and try to involve them in the discussion.

Pelayo Alvarez, Carbon Cycle Institute: Inquired on the timeframe of the Healthy Soils Initiative. Inquired on how public input will be collected and how the public can participate.
Dr. Gunasekara replied that this meeting is part of the public process in the development of the program. The EFA SAP meeting will continue to be the public venue for Healthy Soils discussions and open to the public. Interagency coordination is also occurring; there is a 2-page document available on goals for the initiative on CDFA Environmental Stewardship webpage.

Adam Kotin, CalCAN: Inquired if there have been further conversations on goals for the initiative or opportunities for public involvement.
Dr. Gunasekara responded that there would be further public and stakeholder conversations on the potential of setting SOM goals.

Nick Lapis, Californians Against Waste: The 2-page document on the initiative includes interesting short term and long term goals. Commented that it would be helpful to know how we are going to reach these goals.
Dr. Gunasekara responded that this meeting is part of reaching the goals. Multiple agencies are participating. Different agencies will take different actions. CDFA is using SAP to determine what to focus on.

AGENDA ITEM 5 – ADJOURN

Chair Cameron adjourned the meeting at 2:47 PM.

Respectfully submitted by:

_____ _____
Amrith Gunasekara, Ph.D. Date

DRAFT

STATE WATER EFFICIENCY AND ENHANCEMENT PROGRAM

Amrith (Ami) Gunasekara, PhD
Science Advisor

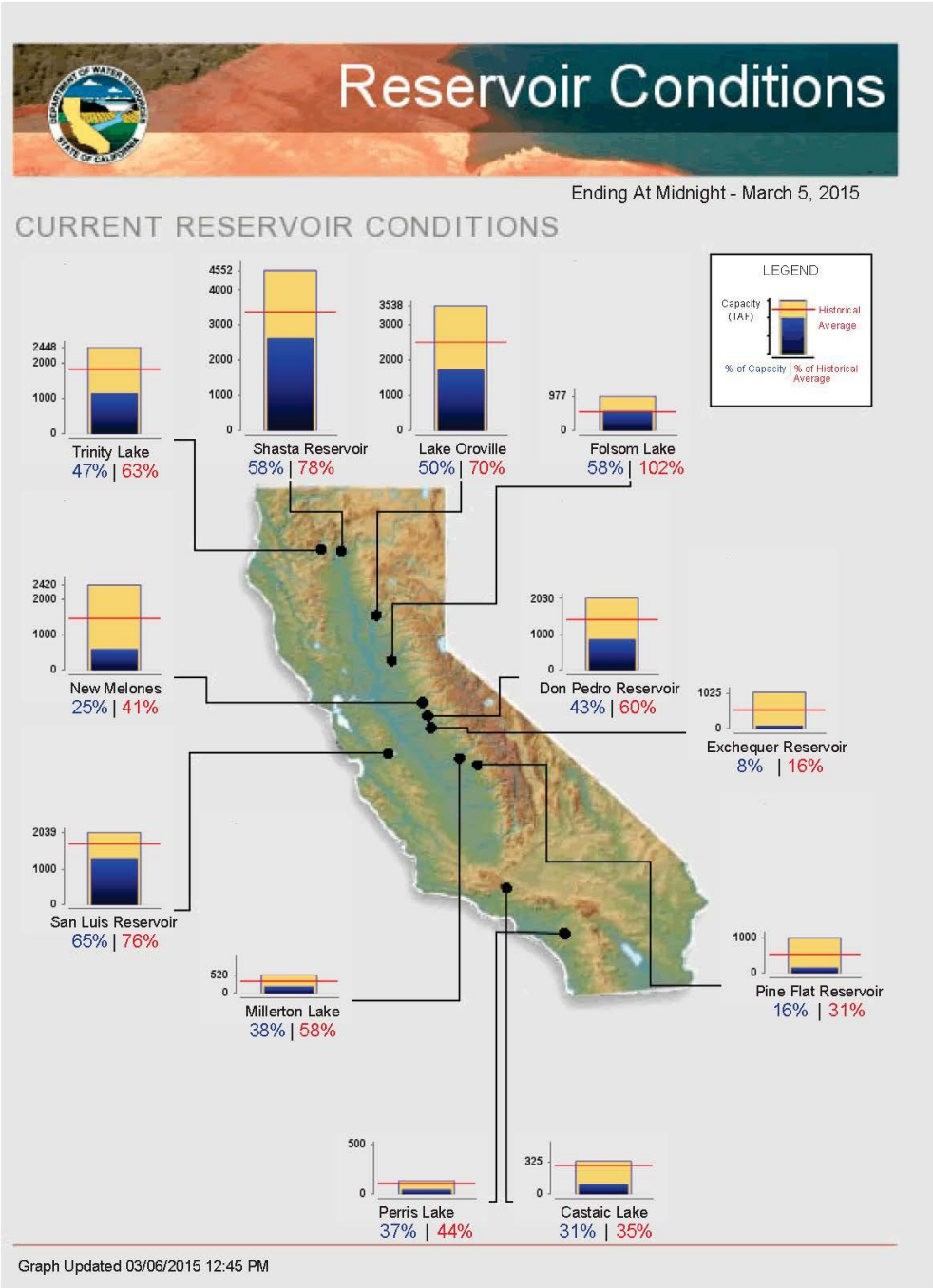
Environmental Farming Act
Science Advisory Panel

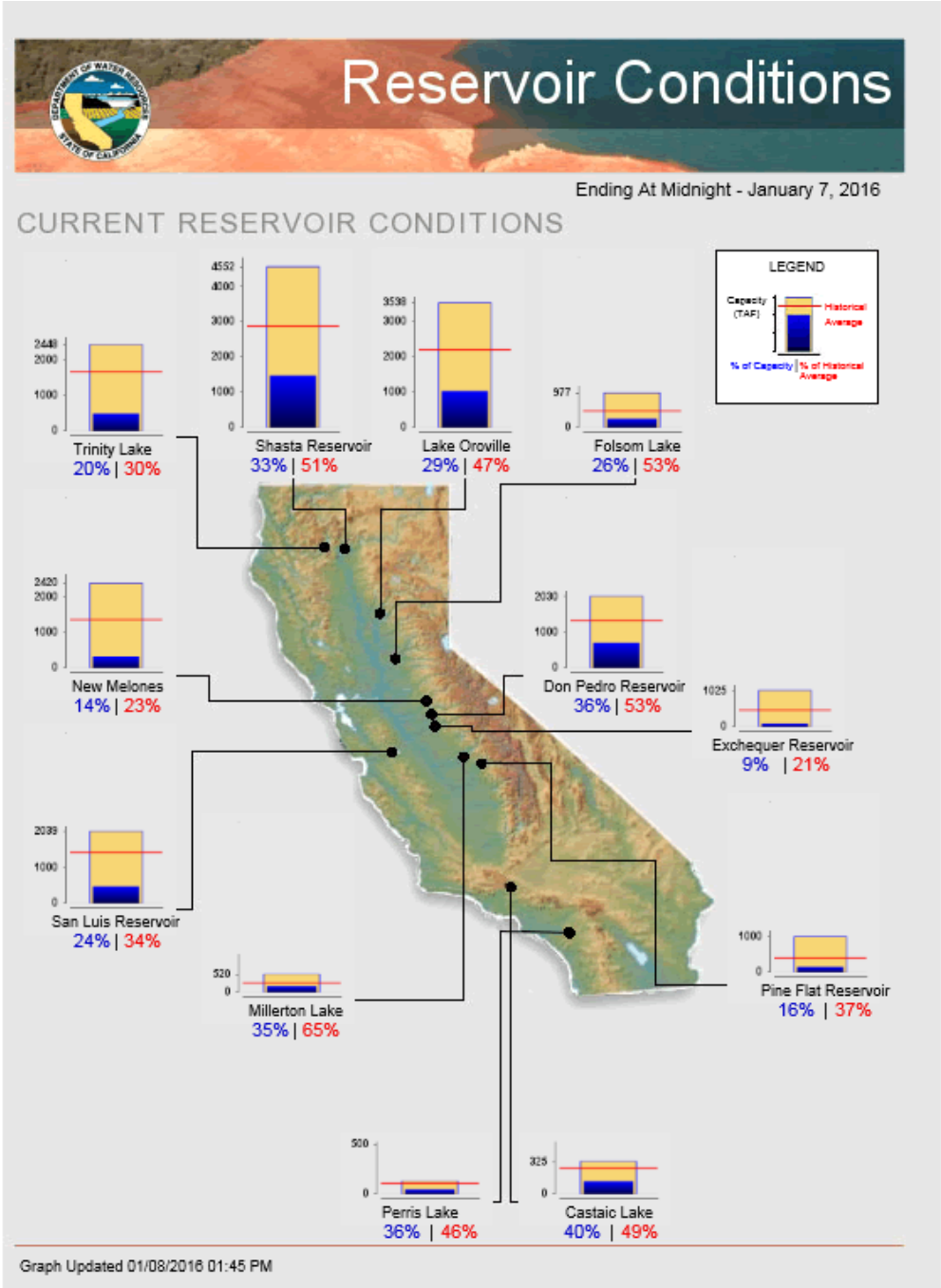
January 15, 2016

cdfa CALIFORNIA DEPARTMENT OF FOOD & AGRICULTURE

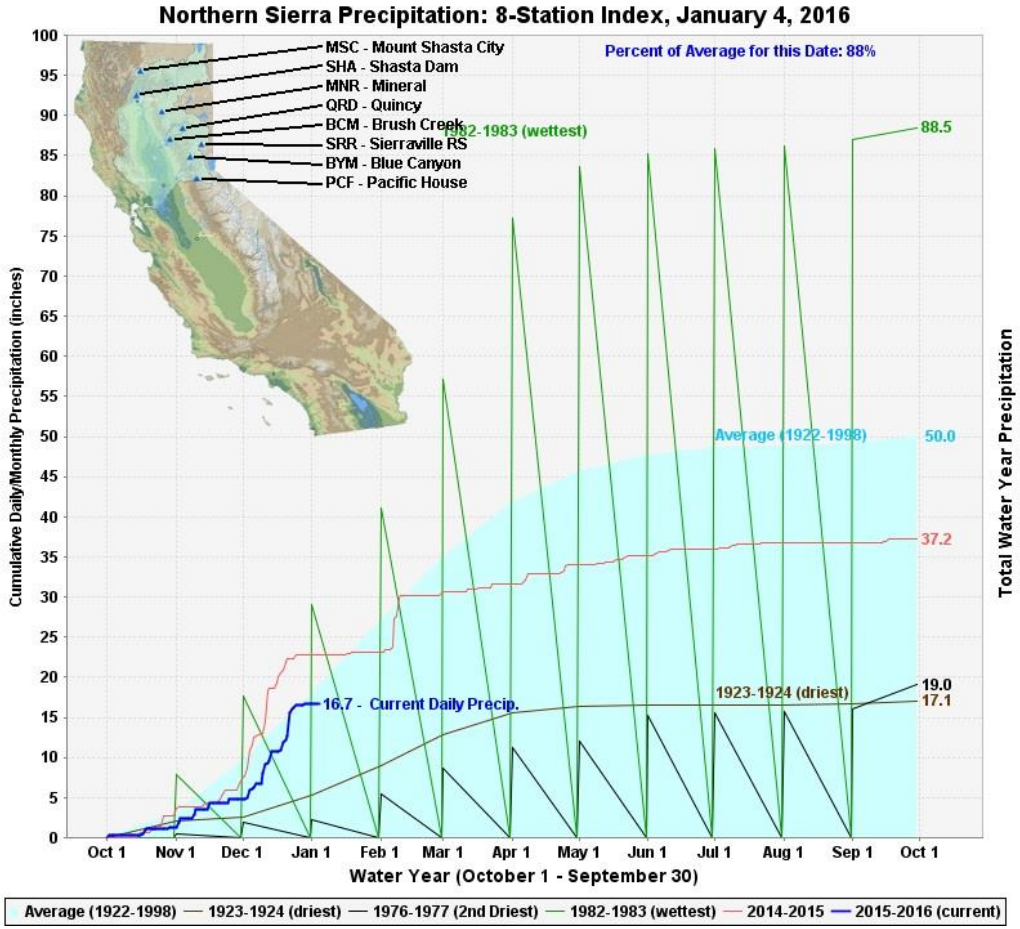
CALIFORNIA ENVIRONMENTAL PROTECTION AGENCY
STATE WATER RESOURCES CONTROL BOARD

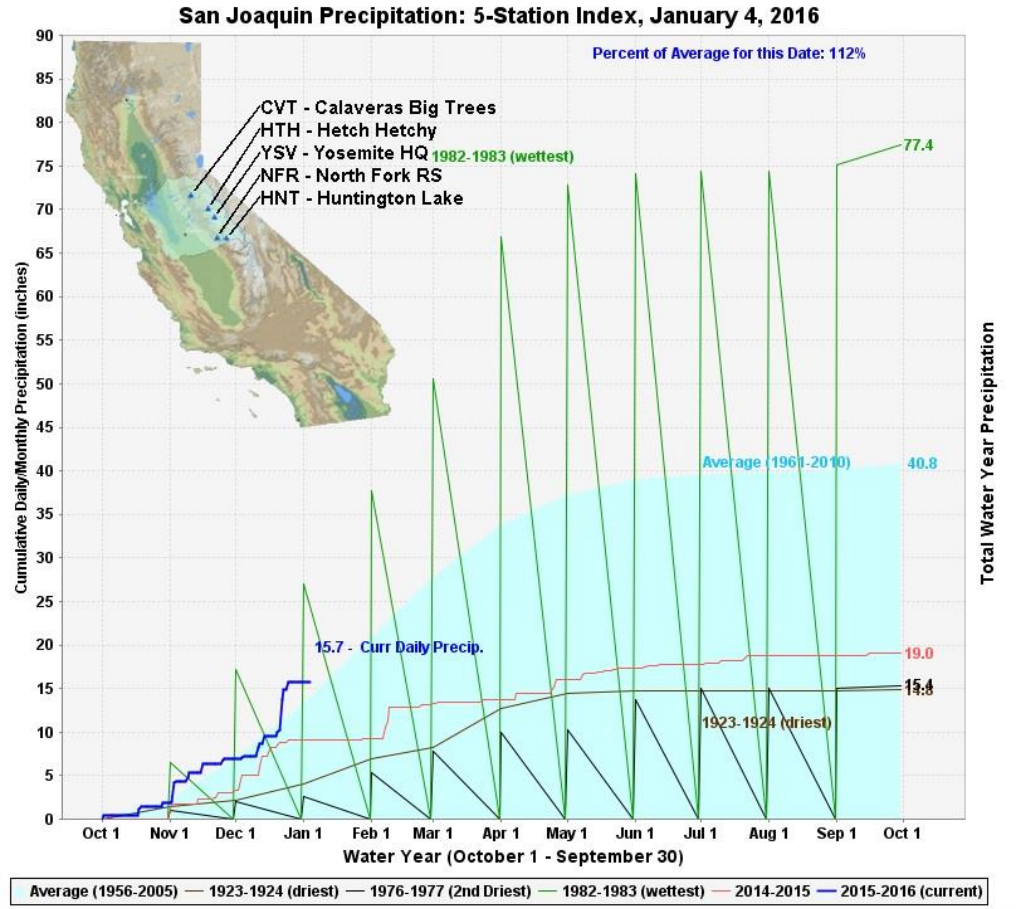
CALIFORNIA DEPARTMENT OF
WATER RESOURCES


Reservoir Conditions
Ending At Midnight - March 5, 2015
CURRENT RESERVOIR CONDITIONS
LEGEND
Capacity (TAF)
Historical Average
% of Capacity | % of Historical Average
Trinity Lake
47% | 63%
Shasta Reservoir
58% | 78%
Lake Oroville
50% | 70%
Folsom Lake
58% | 102%
New Melones
25% | 41%
Don Pedro Reservoir
43% | 60%
Exchequer Reservoir
8% | 16%
San Luis Reservoir
65% | 76%
Millerton Lake
38% | 58%
Pine Flat Reservoir
16% | 31%
Perris Lake
37% | 44%
Castaic Lake
31% | 35%
Graph Updated 03/06/2015 12:45 PM


Reservoir Conditions
Ending At Midnight - January 7, 2016
CURRENT RESERVOIR CONDITIONS
LEGEND
Capacity (TAF)
Historical Average
% of Capacity | % of Historical Average
Trinity Lake
20% | 30%
Shasta Reservoir
33% | 51%
Lake Oroville
29% | 47%
Folsom Lake
26% | 53%
New Melones
14% | 23%
Don Pedro Reservoir
36% | 53%
Exchequer Reservoir
9% | 21%
San Luis Reservoir
24% | 34%
Millerton Lake
35% | 65%
Pine Flat Reservoir
16% | 37%
Perris Lake
36% | 46%
Castaic Lake
40% | 49%
Graph Updated 01/08/2016 01:45 PM

Source: DWR


Northern Sierra Precipitation: 8-Station Index, January 4, 2016
Percent of Average for this Date: 88%
MSC - Mount Shasta City
SHA - Shasta Dam
MNR - Mineral
QRD - Quincy
BCM - Brush Creek
SRR - Sierraville RS
BYM - Blue Canyon
PCF - Pacific House
1982-1983 (wettest)
88.5
Average (1922-1998)
50.0
37.2
1923-1924 (driest)
19.0
17.1
16.7 - Current Daily Precip.
Cumulative Daily/Monthly Precipitation (inches)
Total Water Year Precipitation
Oct 1 Nov 1 Dec 1 Jan 1 Feb 1 Mar 1 Apr 1 May 1 Jun 1 Jul 1 Aug 1 Sep 1 Oct 1
Water Year (October 1 - September 30)
Average (1922-1998) 1923-1924 (driest) 1976-1977 (2nd Driest) 1982-1983 (wettest) 2014-2015 2015-2016 (current)


San Joaquin Precipitation: 5-Station Index, January 4, 2016
Percent of Average for this Date: 112%
CVT - Calaveras Big Trees
HTH - Hetch Hetchy
YSV - Yosemite HQ
NFR - North Fork RS
HNT - Huntington Lake
1982-1983 (wettest)
77.4
Average (1961-2010)
40.8
19.0
15.4
14.8
1923-1924 (driest)
15.7 - Curr Daily Precip.
Cumulative Daily/Monthly Precipitation (inches)
Total Water Year Precipitation
Oct 1 Nov 1 Dec 1 Jan 1 Feb 1 Mar 1 Apr 1 May 1 Jun 1 Jul 1 Aug 1 Sep 1 Oct 1
Water Year (October 1 - September 30)
Average (1956-2005) 1923-1924 (driest) 1976-1977 (2nd Driest) 1982-1983 (wettest) 2014-2015 2015-2016 (current)

Source: DWR

STATE WATER EFFICIENCY AND ENHANCEMENT PROGRAM (SWEEP)

- Emergency drought legislation bill (SB 103) signed by Governor Brown on March 1, 2014.
  - $10 million – for 2014-15
- AB 91 allocated additional funds in March 27, 2015.
  - $10 million – for 2015-16
- SB 101signed by Governor in September 24, 2015, allocated additional funds
  - $40 million – for 2016-17 – Application deadline was last Friday

…..from the **California Climate Investments** fund (Cap and Trade Revenue $) for the California Department of Food and Agriculture to invest in irrigation and water pumping systems that **reduce water use, energy use and greenhouse gas emissions**.

SWEEP by the NUMBERS

- SWEEP 2014-15 funded $8.5 million for 133 different projects
  Total requested was $33.4 million for 453 applications
  Total matching funds was $5.9 million

  - 67% - Soil moisture monitoring systems for better scheduling
  - 37% - Micro-irrigation/drip systems
  - 26% - Energy efficient pumps (switch to electric or solar)
  - 28% - Use of ET data and scheduling
  - 15% - Use of variable frequency drive (VFD) pumps
  - 5% - Use of low pressure irrigation systems

- SWEEP 2015-16 funded $9.38 million for 100 different projects
  Total requested was $30 million for 345 applications

- Program oversubscribed by 300%

SWEEP by the NUMBERS

2014-15 GHG and Water Estimates

GHG reductions = 51,627 Tonnes CO_2e/yr (life of practice is 10 years)

Equivalent to removing the following number of vehicles from the road (based on 4.7 Tonnes of CO2e/yr per vehicle – U.S. EPA from 21.6 miles per gallon and 11,400 miles per year) = 10,984 vehicles/yr

Water savings = 24,529 acre feet/yr

Number of 15,000 gallon (average pool size) pools per year = 532,851 pools per year
Number of 1 gallon bottles = 8 billion

New Requirements for 2015-16

Post-project quantification of GHGs and Water Savings = 3 yrs

All growers must maintain records to support savings = 3 yrs

SWEEP by the CROPS

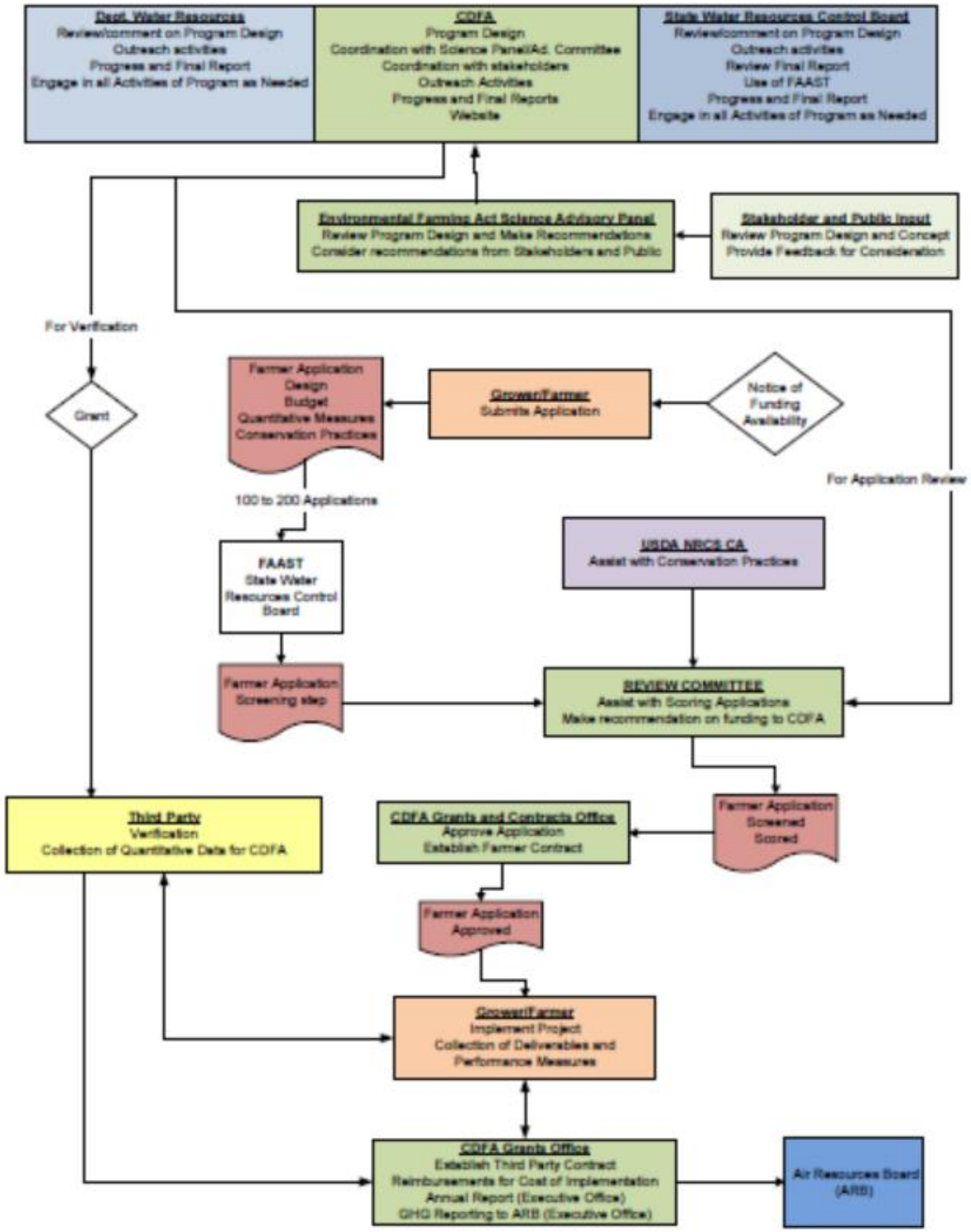
2014-2015 - $10 million

- Tomatoes, alfalfa, walnuts, citrus, strawberries, garbanzo beans, cotton, olives, cole and lettuce crops, stone fruit, vegetables, table grapes, almonds, lemons, avocado, pistachio, wine grapes, pasture/hay, apricots, greenhouse vegetables and flowers, prunes, thyme, rosemary, cilantro, oregano, dill, forage crops, garlic, onion, wheat, carrots, peaches, nectarines, figs, melons, blackberries, asparagus seed, hops, apples, corn, wheat/oats, milo grain, wholesale nursery (annuals and perennials), cherries, raspberries, cucumber

2015-2016 - $10 million

- wine grapes, pecans, walnuts, pasture, corn, tomatoes, almonds, pomegranates, alfalfa, seed for lettuce, onions, romaine lettuce, spring lettuce, head lettuce, celery and sprouts, cotton, Asian specialty vegetables, peppers, eggplant, snow peas, green beans, squash, bulb and green onions, plums, oranges (citrus), pistachios, sunflowers, cherries, stone fruit, avocado, vegetables (beets, broccoli, cabbage, carrots, fennel, radishes, spring mix), raisin grapes, apples, pears, kiwis, raspberries, blackberries, mandarins

CDFA Water Efficiency and Enhancement Program



Planting Seeds

FOOD & FARMING NEWS FROM CDFA

← California leads nation in floriculture production – From the USDA's National Agricultural Statistics Service

Secretary Ross teams up with Visit California to promote agritourism – from the Fresno Bee →

State Water Efficiency and Enhancement Program (SWEEP) built on collaborative partnerships

Posted on June 30, 2014 by Dr. Amrith Gunasekara, CDFA Science Advisor

CDFA continues to accept applications for the State Water Efficiency and Enhancement Program, or SWEEP. The deadline to apply is July 15, 2014.

The program is designed to provide financial assistance to agricultural operations for the implementation of water conservation measures that increase water efficiency and reduce greenhouse gas emissions. Approximately $10 million has been made available for SWEEP through emergency drought legislation (Senate Bill 103).

ACKNOWLEDGMENTS

Development and Oversight

- Department of Water Resources
- State Water Resources Control Board
- Air Resource Board

Program Advisors

- CDFA's Environmental Farming Act, Science Advisory Panel
- USDA Natural Resource Conservation Service
- Public Comments
- Agricultural Associations and stakeholders

Third Party Involvement

- CA Association of Resource Conservation Districts
- Resource Conservation Districts
- Cal Poly Irrigation Training & Research Center
- CSU Fresno Center for Irrigation Technology
- University of California

CDFA SWEEP Team

Carolyn Cook, Crystal Meyers, Sarah Weaver, Laura Battise,

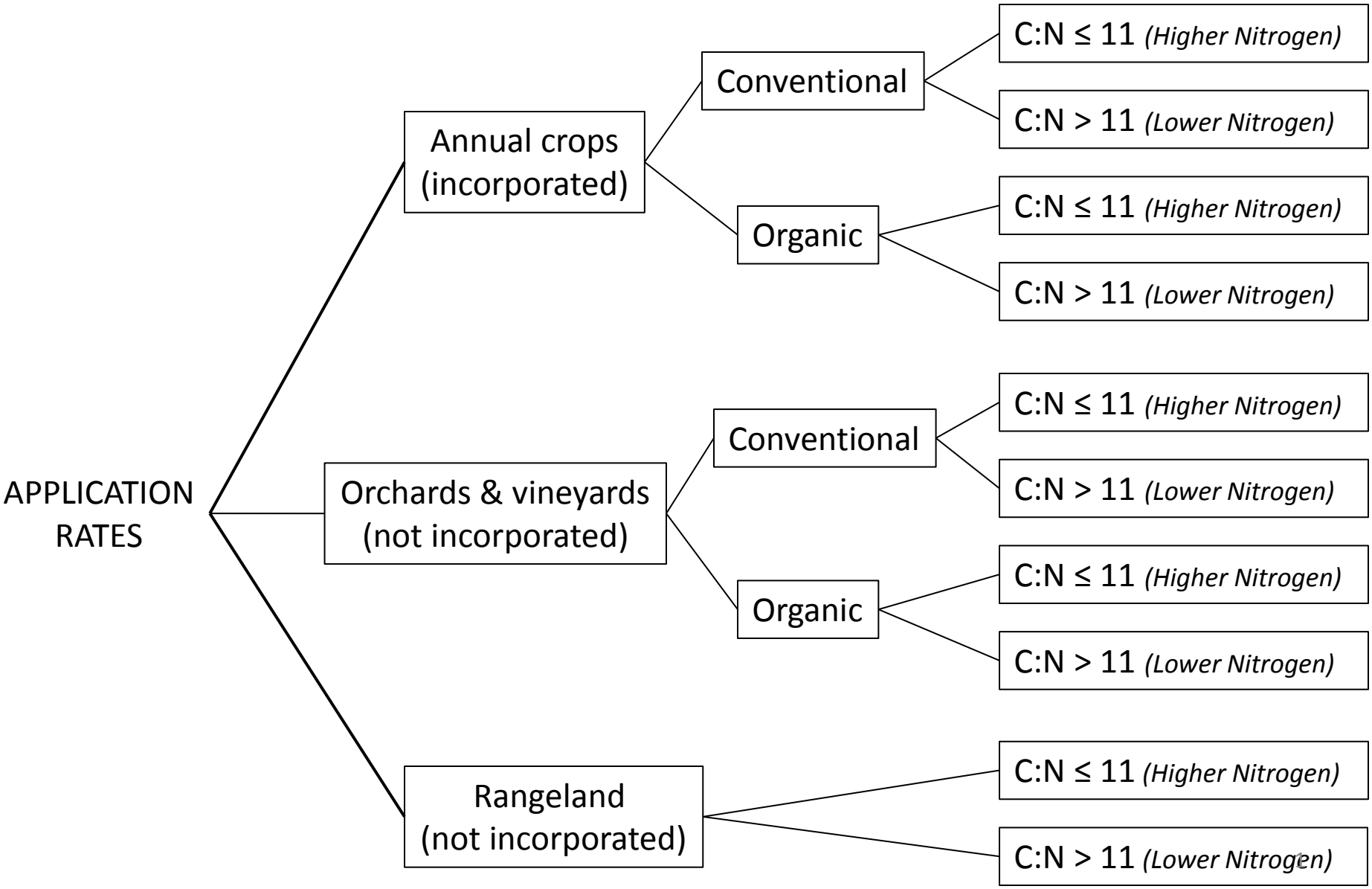
Agronomic rates of compost application for California croplands and rangelands to support a CDFA Healthy Soils Incentives Program

Environmental Farming Act
Science Advisory Panel Meeting
January 15, 2016

Kelly Gravuer
PhD Candidate, UC Davis & Graduate Student Assistant, CDFA
klgravuer@ucdavis.edu

From August 28, 2015 subcommittee meeting:

Ten rates to define based on crop + management + compost type



Summary of proposed application rates
(moist tons per acre per year)

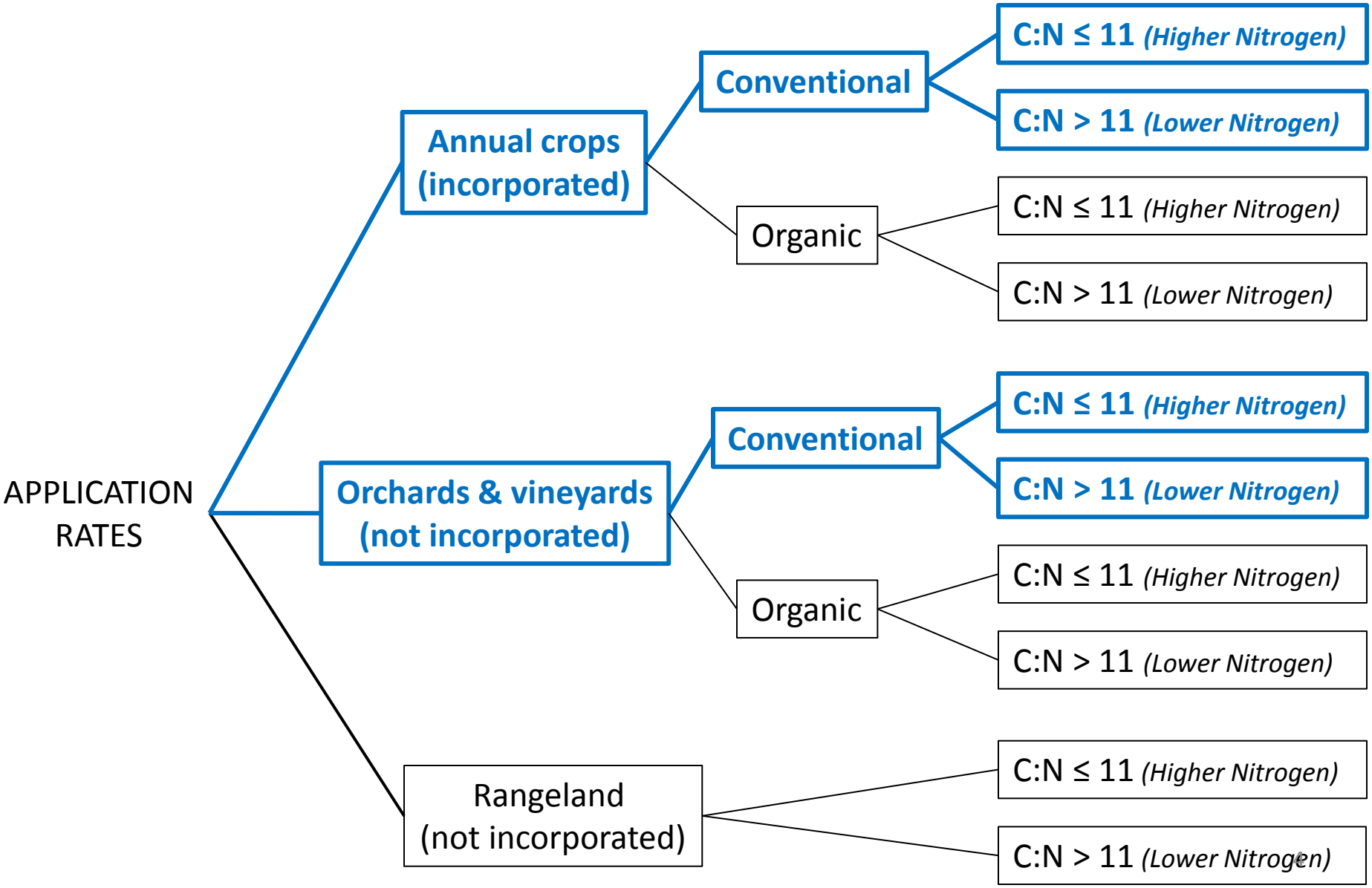
Annual crops (incorporated)	Conventional	C:N ≤ 11 *(Higher Nitrogen)*	3 - 5
		C:N > 11 *(Lower Nitrogen)*	8
	Organic	C:N ≤ 11 *(Higher Nitrogen)*	3 - 5
		C:N > 11 *(Lower Nitrogen)*	8
Orchards & vineyards (not incorporated)	Conventional	C:N ≤ 11 *(Higher Nitrogen)*	2 - 4
		C:N > 11 *(Lower Nitrogen)*	6 - 8
	Organic	C:N ≤ 11 *(Higher Nitrogen)*	2 - 4
		C:N > 11 *(Lower Nitrogen)*	6 - 8
Rangeland (not incorporated)		C:N ≤ 11 *(Higher Nitrogen)*	5 - 10
		C:N > 11 *(Lower Nitrogen)*	15 - 30

General approach to defining application rates

- Set **upper bound** based on **potential environmental impact(s)**

- **Lower bound** could be relatively close to upper bound to **maximize C sequestration** and soil health improvement potential

First focus: **Conventionally-managed crops**



Approach: Consider nitrate leaching as environmental impact of concern

- Need to know compost's available (inorganic) nitrogen (N) content and its organic N content (e.g., proteins), as well as rate at which the organic N will be mineralized to available N

- Year 1 organic N mineralization rates from CA literature reviews[1-5]:
  - Higher N compost: 7-15% in year of application; average ≈ 10%
  - Lower N compost: 2-7% in year of application; average ≈ 5%

- "Textbook" halving of % organic N mineralized each subsequent year[3]:
  - If 10% of total organic N in year 1, then
  - 5% of remaining organic N in year 2
  - 2.5% of remaining organic N in year 3
  - etc.

- Assume all inorganic N (ammonium and nitrate) in applied compost is either used or lost from system in year 1 (= year of application)

Estimating available N:
Example for higher N compost

- Data from CalRecycle analysis of 1364 compost samples, summarized for higher N (C:N ≤ 11) and lower N (C:N > 11) composts separately
- Average N content of *higher N composts (C:N ≤ 11)*:
  - NH4-N per ton dry compost: 1.43 lbs
  - NO3-N per ton dry compost: 0.12 lbs
  - Org-N per ton dry compost (total – NH4-N – NO3-N): 38.12 lbs

Using mineralization rate from literature (10%)[1-5]*:*

- N available in **year 1** = NH4-N + NO3-N + [0.10*Org-N] = **5.36 lbs** per dry ton
- N available **year 2** = (0.10/2) * remaining Org-N = **1.72 lbs** per dry ton
- N available **year 3** = (0.10/4) * remaining Org-N = **0.81 lbs** per dry ton
- etc.

Approach: Compare available N from compost to total plant required N‡ for each crop type

- Identify total plant required N for each crop type‡
- Consider compost application rates from the perspective of: *what percentage of total plant required N does the available N from the compost represent?*
- Example 1: Apply **lower N compost to tree crop**
  - N available in year 1: 1.91 lbs per ton dry compost
    - Consider only year 1 for now; could also consider longer-term release
  - *Average* total plant required N for tree crops ‡: 115 lbs/acre
    - Total plant required N can be up to 380 lbs/acre for tree crops
  - Average % moisture of lower N compost = 34.14%
- If applying **5 moist tons** of lower N compost per acre :
  - 5*(1- 0.3414) = 3.29 tons dry compost equivalent
  - 3.29 * 1.91 = 6.27 lbs N applied per acre
  - 6.27 / 115 = **5.5% of total plant required N added by compost**

‡ recommendations from FREP/UC Davis: http://apps.cdfa.ca.gov/frep/docs/Guidelines.html

Approach: Compare available N from compost to total plant required N‡ for each crop type *(cont.)*

- Example 2: Apply **higher N compost to annual crop**
  - N available in year 1: 5.36 lbs per ton dry compost
    - Consider only year 1 for now; could also consider longer-term release
  - *Average* total plant required N for annual crops‡: 161 lbs/acre
    - Total plant required N can be up to 270 lbs/acre for annuals
  - Average % moisture of higher N compost = 27.11%
- If applying **4 moist tons** of higher N compost per acre :
  - 4*(1- 0.2711) = 2.92 tons dry compost equivalent
  - 2.92 * 5.36 = 15.6 lbs N applied per acre
  - 15.6 / 161 = **9.7% of total plant required N added by compost**

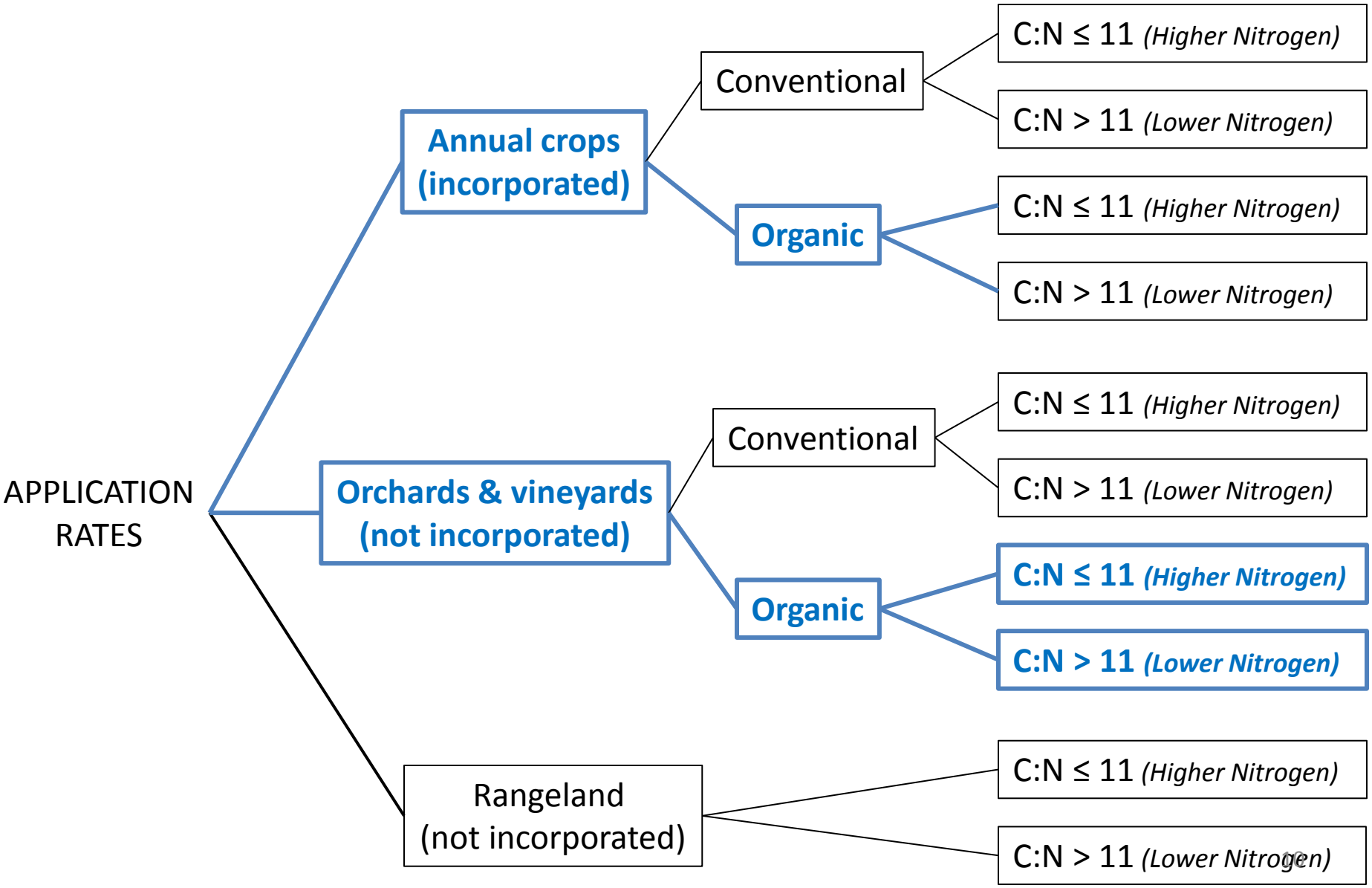
‡ recommendations from FREP/UC Davis: http://apps.cdfa.ca.gov/frep/docs/Guidelines.html

Set application rates to be *below* 15% of total N required by crop

Crop Type	Compost Type	Moist Compost Application Rate (tons/acre)	Equivalent Dry Compost Application Rate (tons/acre)	% of total plant required N represented by rate
Annual	Higher N (C:N ≤ 11)	3 – 5	2.2 – 3.6	7.3 – 12.1%
Annual	Lower N (C:N > 11)	8	5.3	8.1%
Tree	Higher N (C:N ≤ 11)	2 – 4	1.5 – 2.9	6.8 – 13.6%
Tree	Lower N (C:N > 11)	6 – 8	4.0 – 5.3	8.6 – 11.4%

- 15% considered a "change" by NRCS
- For program, use "equivalent dry compost application rates" - convert to actual application rates on a batch-specific basis
- Upper bound of 8 tons set by expert recommendation to reflect grower preferences
- *Lower N compost* rates are higher due to lower N content + slower estimated mineralization

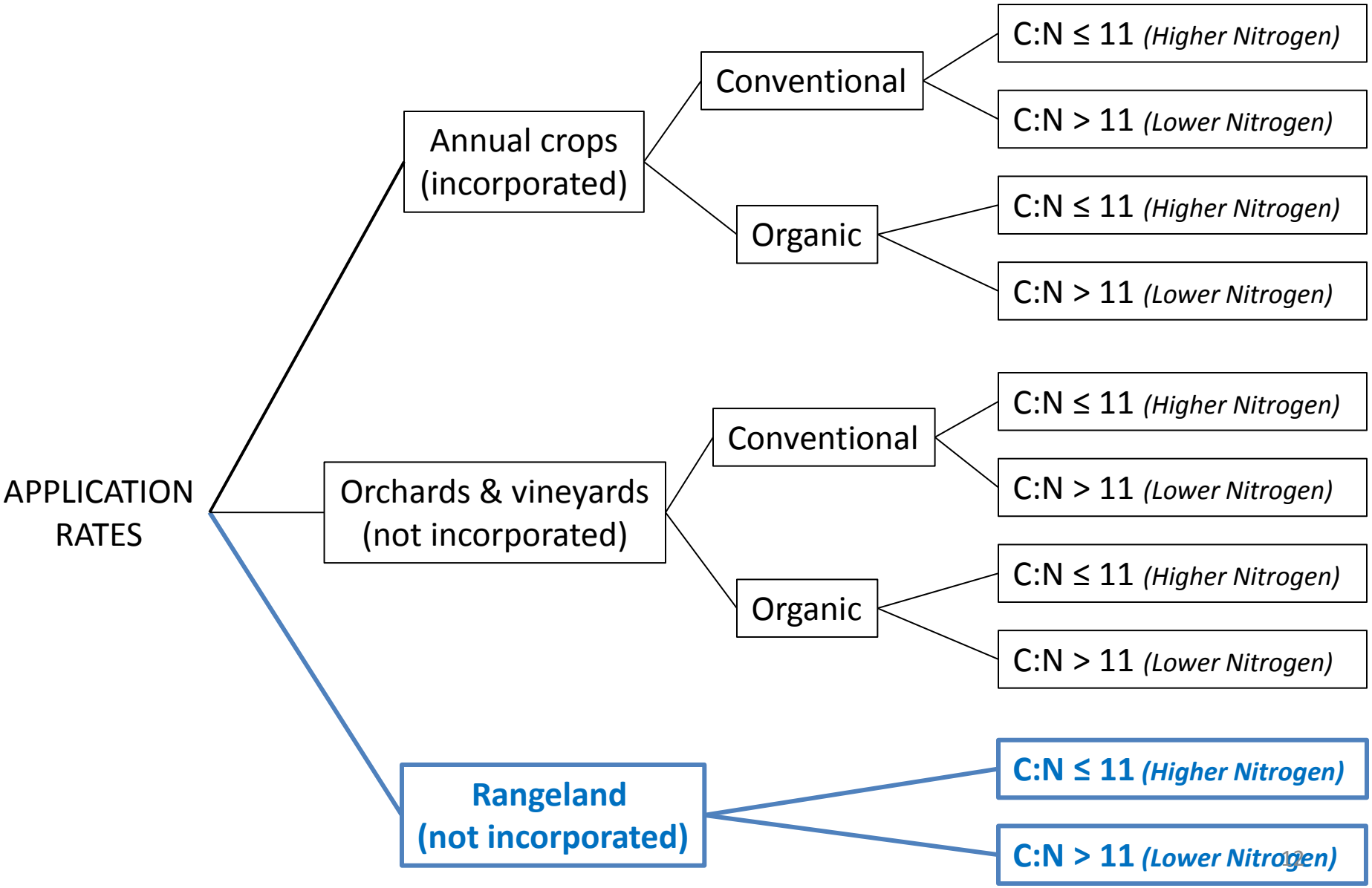
Organically-managed crops



Organically-managed crops

- May be no “one size fits all” agronomic rate of compost application for organic growers – plays different roles in different growers’ fertility management systems
- Still want to include organic growers in program
- **Propose to cost share for same application rates used for conventionally-grown crops,** though organic growers may apply higher rates in total

Rangelands


APPLICATION RATES
Annual crops (incorporated)
Conventional
C:N ≤ 11 (Higher Nitrogen)
C:N > 11 (Lower Nitrogen)
Organic
C:N ≤ 11 (Higher Nitrogen)
C:N > 11 (Lower Nitrogen)
Orchards & vineyards (not incorporated)
Conventional
C:N ≤ 11 (Higher Nitrogen)
C:N > 11 (Lower Nitrogen)
Organic
C:N ≤ 11 (Higher Nitrogen)
C:N > 11 (Lower Nitrogen)
Rangeland (not incorporated)
C:N ≤ 11 (Higher Nitrogen)
C:N > 11 (Lower Nitrogen)

California Rangelands

- Cover over 41 million acres in CA (30-40% of CA land area)
- Generally grasslands or woodlands with grassy understory
  - Most grasslands dominated by non-native annual grasses, some by native and/or non-native perennial grasses
  - Often a diverse group of native and non-native forbs (AKA wildflowers) present at lower abundance
- Soils have significant C storage and potential for additional C sequestration
- Often on hilly terrain
- Management often includes grazing strategies and removal of problematic plants, but does not usually include intensive inputs (fertilizer, irrigation, etc.)

Rangeland rate considerations

- Peer-reviewed studies of two northern CA sites showed significant C sequestration potential (Ryals & Silver 2013, Ecol App 23: 46–59)
  - NRCS is coordinating more studies across diverse environments
- What concern(s) should set upper application rate bound?
  - Potential for nitrate leaching?
    - Modeling suggests is unlikely to be a concern at feasible rates, but more field data needed
  - P movement into surface waters?
    - Could reduce risk with site-specific measures
  - Nutrient addition effects on plant diversity and wildlife habitat?
    - Diversity declines in studies adding high amounts of synthetic nutrients
    - Compost much less nutrient-dense, but little research on thresholds
    - Assume this is most sensitive ecosystem attribute for now

What levels of nutrient addition have detectable impacts on plant diversity?

- Very few systematic studies of grassland responses to *nutrient application rate gradients* in CA – most add nutrients at a rate expected to have an impact
- Some attempts to define "critical load" of N deposition for ecosystem integrity – but sparse data for CA grasslands
- Strategy: literature review of studies that added organic amendments to semi-arid rangelands and assessed impact on plant diversity
  - Ideally only for composted amendments, but studies sparse, so included uncomposted amendments as well
- Focusing on N here; results similar when focused on P

Review of organic amendment additions to semi-arid rangelands

- 9 studies (amendments: 4 composted, 5 not composted)
- Plant community observed an average of 4 years after amendment application
- Effect threshold rate was approximately 36 lbs (cumulative) available N per acre
  - Below 36 lbs available N per acre, 100% of studies observed **NO IMPACT** on plant diversity
    - = 5 tons/acre higher N compost & 15 tons/acre lower N compost
    - Suitable for most rangelands
  - Between 36 and 65 lbs, 50% of studies observed impact
    - = 10 tons/acre higher N compost & 30 tons/acre lower N compost
    - Suitable for special situations, e.g. highly degraded rangelands
  - Above 65 lbs available N per acre, 89% of studies observed **IMPACT** on plant diversity

Proposed strategy for rangelands

- **Incentivize rates that should not have significant impacts**, based on currently available information
  - Higher N compost: 5(– 10) tons/acre
  - Lower N compost: 15(– 30) tons/acre
- **Demonstration projects using range of rates** across diverse sites/conditions – if minimal impacts observed, could incentivize higher rates at later time
- Develop list of **plant community types that are ineligible** (e.g., serpentine grasslands) - build on American Carbon Registry (ACR) consideration of this issue
- **Site assessment by professional** qualified to assess relevant risks for each project (also required by ACR)

Summary of proposed application rates
(moist tons per acre per year)

- **Annual crops (incorporated)**
  - **Conventional**
    - C:N ≤ 11 *(Higher Nitrogen)* — **3 - 5**
    - C:N > 11 *(Lower Nitrogen)* — **8**
  - **Organic**
    - C:N ≤ 11 *(Higher Nitrogen)* — **3 - 5**
    - C:N > 11 *(Lower Nitrogen)* — **8**

    Amount to cost share; amount applied by grower may be higher

- **Orchards & vineyards (not incorporated)**
  - **Conventional**
    - C:N ≤ 11 *(Higher Nitrogen)* — **2 - 4**
    - C:N > 11 *(Lower Nitrogen)* — **6 - 8**
  - **Organic**
    - C:N ≤ 11 *(Higher Nitrogen)* — **2 - 4**
    - C:N > 11 *(Lower Nitrogen)* — **6 - 8**

    Amount to cost share; amount applied by grower may be higher

- **Rangeland (not incorporated)**
  - C:N ≤ 11 *(Higher Nitrogen)* — **5 - 10**
  - C:N > 11 *(Lower Nitrogen)* — **15 - 30**

N mineralization rate literature sources

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Note: the literature on rates of nitrogen mineralization from compost is vast and highly variable. These particular sources were chosen because they were reviews and/or California-specific.

Organic amendment effects on rangeland plant diversity: Literature sources

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  - Pedrol, N. *et al.* (2010) Soil fertility and spontaneous revegetation in lignite spoil banks under different amendments. Soil & Tillage Research 110: 134-142.
  - Martínez, F. *et al.* (2003) biowaste effects on soil and native plants in a semiarid ecosystem. Journal of Environmental Quality 32:472-479.
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- **Not composted**
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  - Pierce, B.L. *et al.* (1998) Plant biomass and elemental changes in shrubland forages following biosolids application. Journal of Environmental Quality 27:789-794.
  - Stravast, L.J. *et al.* (2005) New Mexico blue grama rangeland response to dairy manure application. Rangeland Ecology & Management 58:423-429.
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Agronomic rates of compost application for California croplands and rangelands to support a CDFA Healthy Soils Incentives Program

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Executive Summary

As part of Governor Brown's Healthy Soils Initiative, the California Department of Food and Agriculture (CDFA) is planning to establish a financial incentivize program for California's farmers and ranchers to implement practices that improve soil health and reduce greenhouse gas (GHG) emissions. These incentives would be based on the COMET-Planner tool, which estimates GHG reductions from agricultural management practices. However, one agricultural practice with considerable soil health improvement and GHG reduction potential is not yet included in the COMET-Planner tool. The application of compost to croplands and rangelands is an important management practice that can improve soil health. In order to make this management practice included in any future incentive program by CDFA, agronomic compost application rates need to be established.

At the recommendation of the Environmental Farming Act Science Advisory Panel, CDFA convened a subcommittee of scientific experts to propose best-available scientific-based agronomic rates of compost application. This expert group proposed distributing composts into two major categories: those with higher nitrogen (C:N ≤ 11) and those with lower nitrogen (C:N > 11) content. The group also proposed dividing California cropping systems into two major types (annual crops and tree crops) and considering croplands and rangelands separately.

The subcommittee recommended a maximum agronomic rate of 8 moist (i.e., as purchased) tons of compost/acre/year based on current grower practices and best-available science. Agronomic rates of moist compost application for croplands were: for annual crops, 3-5 tons/acre/year for higher nitrogen (C:N ≤ 11) compost and 8 tons/acre/year for lower nitrogen (C:N > 11) compost; and for tree crops, 2-4 tons/acre/year for higher nitrogen compost and 6-8 tons/acre/year for lower nitrogen compost.

Agronomic rangeland application rates were recommended at 5-10 tons/acre for higher nitrogen compost and 15-30 tons/acre for lower nitrogen compost. However, because specific field data on rangeland compost application in California is still very limited, it is vital to continue documenting effects of this practice and adjust agronomic rates according to site specifications. Additional information on the science and logic on how these rates were proposed by the expert group is described in this report.

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Introduction

In the 2015-16 proposed budget, Governor Brown recognized the importance of soil health and directed the California Department of Food and Agriculture (CDFA) to coordinate a new initiative to support and enhance this critical resource. The budget language stated "As the leading agricultural state in the nation, it is important for California's soils to be sustainable and resilient to climate change. Increased carbon in soils is responsible for numerous benefits including increased water holding capacity, increased crop yields and decreased sediment erosion. In the upcoming year, the Administration will work on several new initiatives to increase carbon in soil and establish long term goals for carbon levels in all California's agricultural soils. CDFA will coordinate this initiative under its existing authority provided by the Environmental Farming Act".

Consistent with the Governor's initiative, now titled the Healthy Soils Initiative, CDFA worked with several state agencies to identify short and long-term actions that could improve soil health in California to ensure agricultural sustainability and food security (https://www.cdfa.ca.gov/EnvironmentalStewardship/ pdfs/ShortTermActions.pdf). One of the actions identified was to incentivize management practices that build the carbon content in soils. Increasing the carbon content of soils has been scientifically shown to lead to greater agricultural sustainability and ensure food security, especially in light of climate change. CDFA plans to implement a cost-share incentives program using management practice standards established by the United States Department of Agriculture (USDA) Natural Resources Conservation Services (NRCS). The CDFA program would include soil health-promoting management practices that also reduce greenhouse gas (GHG) emissions. The quantification of GHG reductions is feasible with the recently developed COMET-Planner[1] tool.

An agricultural management practice with significant potential to increase soil carbon content and reduce GHG emissions to the atmosphere in California is not yet being included in the NRCS Management Practice Standards or COMET-Planner. This management practice is the application of compost to croplands and rangelands. This practice can sequester carbon in soils and plants by promoting increased soil microbial and plant biomass[2,3], with part of this carbon eventually sequestered as stabilized soil organic matter called humic substances[4,5]. It can also indirectly achieve large GHG emission reductions[6] by providing a market for compost, spurring expansion of composting facilities and organic waste diversion from landfills that produce methane. Methane as a GHG is 28 times more potent than carbon dioxide. Aerobic composting allows the carbon in carbon-based animal and plant source materials to be stabilized into carbon compounds that generally decompose slowly after the compost is applied to land and stimulates a biological process that sequesters carbon into stable long-term carbon fractions. These carbon fractions offer numerous benefits such as increasing the water holding capacity of soils.

Because of the significant potential benefits of compost application and greenhouse gas reductions in California, CDFA must determine "agronomic rates" of compost application to support an incentives program. CDFA will not be able to support unlimited rates of compost application requested by farmers and ranchers given the limited amount of funding available as incentives, as well as the need to ensure that environmental concerns are addressed and that GHG reductions are obtained. In addition, these rates need to be feasible for farmers to implement, based on compost cost, other management needs, and potential changes in yield (if

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any). The amount of anticipated greenhouse gas reduction corresponding to these agronomic rates can then be estimated based on a model from the California Air Resources Board[7], making this practice comparable to other management practice standards listed in COMET-Planner.

Methodology

On July 17, 2015, CDFA convened a meeting of the Environmental Farming Act Science Advisory Panel (EFA SAP) to discuss the application of compost to California croplands and rangelands. The EFA SAP is a group of farmers and scientists who provide scientific guidance to the Secretary of CDFA and acts as a platform for public comment. The EFA SAP functions under the authority of the Environmental Farming Act of 1995 (https://www.cdfa.ca.gov/Environmental Stewardship/pdfs/EnvironmentalFarmingAct.pdf). The meeting was open to the public and was well-attended by a variety of stakeholders. Attendees at the meeting recommended that CDFA convene a subcommittee of compost experts (from academia and state agencies) to evaluate and propose agronomic rates of compost application, which could then be considered for review by the EFA SAP, and subject to public comment and proposed to the Secretary of CDFA to implement as part of any future Healthy Soil incentive program to build soil carbon.

On August 28, 2015, CDFA convened a meeting of this compost subcommittee (herein called expert group). The expert group consisted of university experts in soil science, compost management and agronomy and included scientists from several pertinent state agencies such as CalRecycle, CDFA and the Central Valley Regional Water Quality Control Board (a complete list of participants can be found at the end of this report). The goal of this meeting was to determine how to address agronomic compost application rates given the diversity of cropping systems in California. A second meeting of the expert group was held on September 30, 2015.

Between the two meetings several literature reviews were conducted to evaluate the best available science that would support agronomic rates for compost application to support a CDFA incentives program on soil health. The Results section summarizes the findings of the literature reviews and proposed compost application rates recommended by the expert group.

Results

A major outcome of the expert group meeting on August 28, 2015 was consensus that there is too much variation in the scientific data within both “croplands” and “compost” to define a single application rate. The expert group felt that “croplands” could be usefully divided into annual crops and tree crops and that both conventional and organic management systems should be considered for each of these production systems. Rangelands have different considerations and warranted their own separate category. “Compost” eligible for the program should be of the “fully composted” type only and could be divided into two further categories (carbon: nitrogen ratio less than and greater than approximately 11). This differentiation, according to the expert group, would separate compost that provided more nitrogen at a faster rate (low C:N) vs. those that provided less nitrogen at a slower rate (high C:N). The group suggested that compost with C:N greater than 11 could be thought of as a practice that is *in addition to* the nutrient management system on the farm, whereas compost with C:N less than 11 could be thought of as a practice that is *part of* the nutrient management system on the

farm. In total, the group identified ten application rates for a CDFA incentives program on building soil carbon (Figure 1).

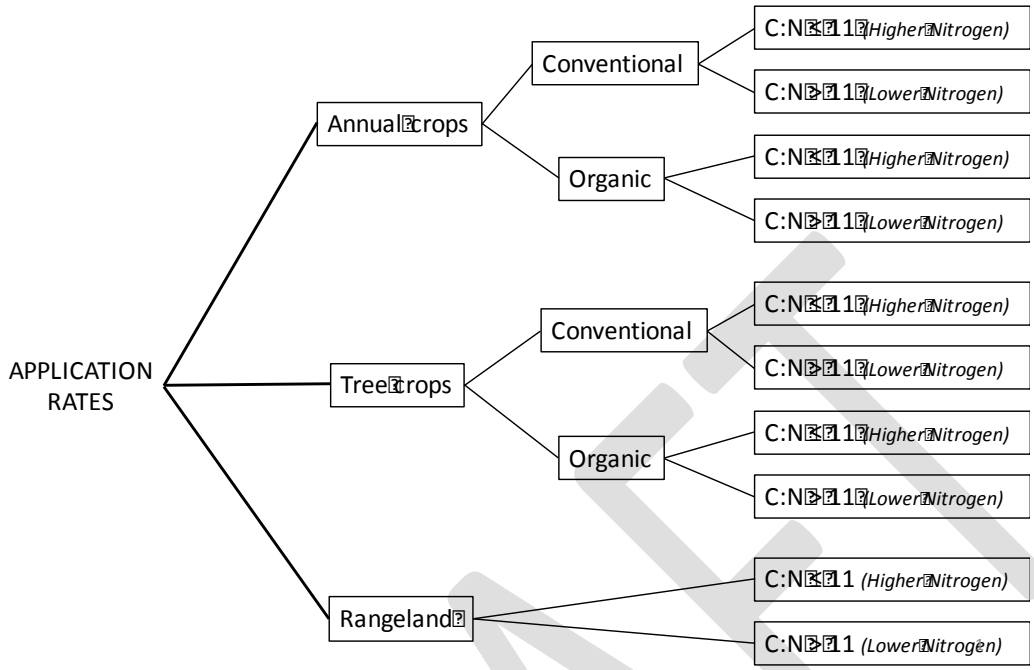

Figure 1. Distribution of application rates to define, as established at August 28, 2015 expert group meeting.

The expert group agreed to a general approach of setting the upper application limit of each application rate range based on best-available scientific data on the potential environmental impact(s) of greatest concern.

Agronomic compost application rates for croplands

The expert group defined the environmental impact of greatest concern to be the potential of increased nitrate leaching to ground water for croplands. Most composts contain small amounts of nitrate as well as other nitrogen compounds that could eventually be converted to nitrate by resident soil microbes. As such, a scientific literature review was conducted to develop estimates of the nitrogen available for conversion to nitrate over time in the two types of composts.

<u>Estimating nitrogen mineralization from compost</u>: Nitrogen in compost can be divided into three main types: nitrate [and nitrite which converts to nitrate rapidly] (NO_3^-; inorganic nitrogen), ammonium (NH_4^+; inorganic nitrogen that can be quickly converted to nitrate by resident soil microbes), and organically-bound nitrogen (nitrogen attached to carbon-containing compounds, which can be slowly converted to ammonium and then nitrate by resident soil microbes). Ammonium and nitrate are the forms of nitrogen typically provided by synthetic fertilizers in conventional agriculture systems (along with urea, which is quickly hydrolyzed to ammonium once applied). The literature review included estimating the rate of

ammonium + nitrate release by compost, and then assuming that the behavior of that ammonium + nitrate would be similar to that of an equivalent amount of applied synthetic ammonium + nitrate (in terms of its potential for uptake by plants or microbes vs. storage in the soil vs. leaching vs. other loss pathways)[i]. The comparison of nitrogen in compost to synthetic fertilizers was made simply to mimic soil physio-chemical behaviors of the nitrogen and not compare the amendment to synthetic fertilizers. It should be noted that this comparison is very different than assuming that adding a certain weight of compost is equivalent to adding the same weight of synthetic fertilizer, as the total ammonium + nitrate available from compost in the year of application tends to be at most 0.3% of its total weight.

Estimating the rate of ammonium + nitrate release by compost requires three pieces of information: the amount (by weight) of ammonium + nitrate in the compost, the amount (by weight) of organically-bound nitrogen in the compost, and a model for the rate at which this organically-bound nitrogen will be converted (mineralized) to ammonium + nitrate. Estimates for the first two information needs (average amounts of ammonium + nitrate and organically-bound nitrogen) were obtained using a CalRecycle database of lab analyses for 1364 compost samples from the southwestern U.S. Composts were first divided into two categories (C:N ≤ 11 and C:N > 11) and average values of these quantities were calculated for each category separately; these averages were medians to avoid undue influence of extreme values (Table 1).

Table 1. Average (median) pounds (lbs) of nitrogen per ton of dry compost and average moisture content for higher nitrogen (C:N ≤ 11) and lower nitrogen (C:N > 11) compost types, as calculated from CalRecycle database of 1364 compost samples.

	Higher N compost (C:N ≤ 11)	Lower N compost (C:N > 11)
Lbs N as ammonium (NH_4^+)	1.43	0.51
Lbs N as nitrate (NO_3^-)	0.12	0.07
Lbs N as organically-bound N	38.12	26.43
Moisture content	27.11%	34.14%

A scientific literature review was completed to address the release of nitrogen from compost. A model for the rate at which organically-bound nitrogen in compost is mineralized to ammonium + nitrate was developed. The literature review was focused on scientific journal articles that synthesized many individual studies and/or studies that were specific to California[8–13]. For the

[i] This is an environmentally conservative assumption. Our estimates of nitrate potentially available for leaching from compost are *at the high end of the possible range*, as it is likely that compost will change soil properties in a way that allows less nitrate to be leached per pound of ammonium + nitrate applied as compared to un-amended fields. Although ammonium + nitrate derived from compost will behave the same as ammonium + nitrate from synthetic fertilizers, the soil matrix into which they are released (which strongly influences their fate of uptake vs. storage vs. leaching vs. loss by other means) will be different as a result of the compost addition. For example, compost generally improves soil water holding capacity, such that less water – potentially carrying nitrate – may leach below the crop root zone in compost-amended fields. However, because the amount of this reduction is highly dependent on soil type along with a range of other management factors, we do not believe it can be quantified reliably at this time and did not attempt to do so.

higher nitrogen type of compost (C:N ≤ 11), studies suggested that 5-15% (average ≈ 10%) of the organically-bound nitrogen would be mineralized in the first year (i.e., the year of application), with the percentage of remaining organically-bound nitrogen mineralized declining by half each subsequent year. Approximately 10% of the organically-bound nitrogen would be mineralized in the first year, 5% of the remaining organically-bound nitrogen in the second year, 2.5% of the remaining organically-bound nitrogen in the third year, etc. For the lower nitrogen type of compost (C:N > 11), studies suggested that 2-7% (average ≈ 5%) of the organically-bound nitrogen would be mineralized in the first year, with a similar pattern of mineralization percentage decline in subsequent years. At a second expert group meeting held on September 30, 2015, the expert group verified that the model was in agreement with existing scientific findings.

Comparing nitrogen from compost to recommended plant nitrogen requirements: With the information noted above, it is possible to estimate the amount of ammonium + nitrate released from compost in a given year following its application (or the cumulative amount released over a chosen number of years). To determine whether this amount would represent a significant addition of ammonium + nitrate to the landscape compared to the plant required nitrogen recommendations that are typically applied each year, plant required nitrogen recommendations for major California crops were reviewed. These recommendations are the result of an intensive literature review conducted by experts at the University of California, Davis in collaboration with CDFA's Fertilizer Research and Education Program (FREP) and are accessible at http://apps.cdfa.ca.gov/frep/docs/Guidelines.html. Plant required nitrogen recommendations were averaged across crops within the two major types: annual crops and tree crops. For annual fruit and vegetable crops (including processing tomatoes, broccoli, lettuce, strawberries, cauliflower, and corn), an average of 161 pounds of nitrogen per acre per year was recommended (with a high of 270 lbs/acre for corn). For established tree crops (including established almonds, walnuts, citrus, pistachios, and plums), an average of 115 pounds of nitrogen per acre per year was recommended (with a high of 380 lbs/acre for almonds). These numbers allowed for the estimated amount of ammonium + nitrate released for a particular application rate, compost type, and crop type to be expressed in units of "% of total plant required nitrogen represented by compost" (Box 1).

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Box 1. Example of calculations to determine the percentage of total plant required nitrogen represented by compost. In this report, application rate recommendations for compost are in terms of "tons moist compost" to allow easy comparison with current compost application rates used by growers. However, % moisture varies widely among composts therefore, the final rate recommendations will be in terms of "tons dry compost", with the grower and compost facility responsible for determining the equivalent moist compost application rate based on the % moisture of the specific compost batch purchased.

Example 1: Apply lower N compost (C:N > 11) to tree crop

- N released by compost in year 1: 1.91 lbs per ton dry compost (1 ton = 2000 lbs) [ammonium-N + nitrate-N + 5% of organically-bound N]
- Average total N required for tree crops: 115 lbs/acre
- Average % moisture of lower N compost = 34.14%

- If applying **5 moist tons** of lower N compost per acre :
  - 5*(1- 0.3414) = 3.29 tons dry compost equivalent
  - 3.29 * 1.91 = 6.27 tons N applied per acre
  - 6.27 / 115 = *5.5% of total required N added by compost*

Example 2: Apply higher N compost (C:N ≤ 11) to annual crop

- N released by compost in year 1: 5.36 lbs per ton dry compost (1 ton = X lbs) [ammonium-N + nitrate-N + 10% of organically-bound N]
- Average total N required for annual crops: 161 lbs/acre
- Average % moisture of higher N compost = 27.11%

- If applying **4 moist tons** of higher N compost per acre :
  - 4*(1- 0.2711) = 2.92 tons dry compost equivalent
  - 2.92 * 5.36 = 15.6 tons N applied per acre
  - 15.6 / 161 = *9.7% of total required N added by compost*

With this framework, the calculation could also be used for other analyses: a percentage of the total nitrogen fertilizer recommendation to be represented by compost could be specified and the corresponding compost application rate determined (Table 2).

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Table 2. Proposed agronomic rates for compost application to croplands. For the N composts with a C:N ratio > 11 (lower N*), composts with C:N ratio > 20-25 are likely to have negligible nitrogen release and may result in nitrogen immobilization. Therefore, as compost C:N increases, it becomes more important to monitor plant and soil conditions after application to ensure there is adequate nitrogen supply for the crop. The rates to use for the proposed incentives program are the "equivalent dry compost application rates"(†), which should be converted to corresponding moist compost application rates on a batch-specific basis using moisture data from the compost facility.

Crop Type	Compost Type	Moist Compost Application Rate (tons/acre)	Equivalent Dry Compost Application Rate (tons/acre)†	% of total plant required N represented by rate
Annual	Higher N (C:N ≤ 11)	3 – 5	2.2 – 3.6	7.3 – 12.1%
Annual	Lower N (C:N > 11)*	8	5.3	8.1%
Tree	Higher N (C:N ≤ 11)	2 – 4	1.5 – 2.9	6.8 – 13.6%
Tree	Lower N (C:N > 11)*	6 – 8	4.0 – 5.3	8.6 – 11.4%

At the second expert group meeting on September 30, 2015, the assembled experts confirmed that the initially proposed rates, with minor modifications that are reflected in Table 2, were reasonable agronomic rates to be used in a CDFA incentive program on soil health.

These rates that would be incentivized by a CDFA healthy soils incentive program would be the same for organic and conventional systems (see Organically-managed croplands section under Other Considerations). The recommended rates do not limit farmers from adding additional compost since these recommended rates have been established on an agronomic and environmental basis to solely support a CDFA healthy soils incentive program.

Agronomic compost application rates for rangelands

In California, the benefits and potential drawbacks of compost application have received far less study on rangelands than on croplands. So far, results from two northern California sites (Yuba County and Marin County, average annual precipitation 730 mm and 950 mm respectively) have been published[3,16,17]. At these sites, adding 31 tons/acre of compost (C:N = 11) resulted in C sequestration of 51 $\pm$ 77 to 333 $\pm$ 52 g C/m^2 over three years, without accounting for the C directly added by the amendment[3]. However, many scientists, including the expert group, have cautioned against extrapolating these results to the full extent of California rangelands, given the considerable diversity of climates and soils throughout the state[18,19]. Thus, while these initial northern California results are encouraging, studies at additional sites across California's climate and soil gradients – as well as with different types of composts (e.g., higher and lower C:N) – are necessary to understand the range of potential C sequestration rates that may be achieved.

Uncertainties about the drawbacks of rangeland compost application are even greater than the uncertainties about its (statewide) C sequestration benefits. In discussions within

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stakeholder meetings, peer review comments on external documents[20,21], and the expert group, three potential drawbacks predominate. First, the potential for increased nitrate leaching to groundwater was mentioned. Second, the potential for declines in plant diversity because nutrient addition could disproportionately favor certain plant species was noted. Thirdly, the stream-dissected sloped rangeland landscape combined with the considerable phosphorus content in many composts raised the concern of phosphorus movement into streams, which could lead to eutrophication (see "Other Considerations" section for discussion of phosphorus). As described below, specific research is not widely available to assess any of these three concerns, but some research studies related to the second concern (plant diversity) provides data on which to define preliminary rangeland application rates.

Potential impacts on nitrate: For nitrate leaching, rangelands would be expected to intercept more of the available nitrogen released from compost than croplands, due at least in part to a greater spatial and temporal extent of plant cover. However, no direct field measurements of nitrate leaching from compost-amended rangelands are available. For the northern California sites, Ryals *et al.*[17] used the DAYCENT model to estimate nitrate leaching in their study. The DAYCENT estimate was approximately 8.9 lbs NO_3-N/acre/year for the first 10 years post-application, which equates to approximately 40% of the N released from the compost leaching out as nitrate over that period (89 lbs NO_3-N/acre of the estimated 222 lbs N/acre released). As we found for croplands, leaching rates were considerably lower for simulations of C:N = 20 and C:N = 30 composts than they were for the C:N = 11 compost that was used in the field study. These estimates now urgently require field-validation and testing at other sites.

Potential impacts on plant diversity: The plant diversity issue was raised by several stakeholders. California rangelands support over 400 plants of conservation concern[22,23] and a number of rangeland wildlife species, some of which are also imperiled, require specific plants and/or vegetation structure for their food and habitat[24–26]. Concerns about the impact of compost addition on plant diversity are grounded in a fairly large body of studies that have documented significant changes in plant community composition – and usually decreases in diversity – in response to synthetic N fertilizer addition[29]. Typically, adding N increases grass biomass more so than forb biomass, such that a few highly-responsive grass species (mostly non-native) can outcompete many of the forbs (mostly native).

However, most of these studies have applied fairly high rates of N (80-100 lbs N/acre/year). There is a lack of scientific peer reviewed studies in California grasslands that have added a range of N rates to determine a threshold rate of N addition above which diversity is likely to decline. A few studies have attempted to determine N "critical loads" at which effects on the ecosystem are discernable[30–32]. These studies suggested that a critical load for California grasslands could be 6-9 lbs N/acre/year, but they are based on limited observational data along an N deposition gradient in serpentine grasslands. Because nutrient-poor serpentine grasslands may be more sensitive to nutrient addition than other California grassland types, more research is needed to evaluate whether this constitutes a basis for a compost application rate upper limit that would be relevant to most California rangelands.

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Defining rates based on potential plant diversity impacts: As a preliminary strategy for setting an upper application limit for compost on rangelands, a literature review of organic amendment applications to rangelands was initiated. Studies meeting the following criteria were included in the review: (1) an organic amendment had been added to a semi-arid or Mediterranean-climate rangeland community (mostly grasslands, sometimes with scattered trees or shrubs), (2) the authors reported the %N of the amendment and enough information to assign it to the "high N" (C:N ≤ 11) or "low N" (> 11) C:N category described above, and (3) plant community diversity had been measured at some point after adding the amendment and compared to that of comparable control plot(s). In total, nine non-redundant studies fit the review criteria; five of which had used non-composted amendments. Most of the studies (including those of composted and non-composted amendments) had applied the amendment at multiple rates, providing 35 study x rate data points, nine of which represented composted amendments. Across these studies, the plant community was observed an average of four years after amendment application. Using the C:N and %N data provided in the studies. The same mineralization model used for croplands (described above) was then used to estimate the cumulative amount of available nitrogen that would have been released from the amendment by the time the plant diversity data was collected. The data points were then sorted by this estimate of nitrogen released (Table 3).

Classification tree analysis suggested that 36 lbs available N/acre was the threshold value that best separated treatments in which plant diversity declined from those in which it did not. Above 65 lbs available N/acre, the likelihood of plant diversity decline becomes significant, suggesting that this value should be the maximum application rate considered. For the rate determinations, slightly more conservative values of 30 and 60 lbs available N/acre were used.

The CalRecycle database estimates of average properties of higher N and lower N composts (Table 1) were used to translate these N thresholds into compost application rates (Table 4). For each type of compost, the "recommended" rate is equivalent to 30 lbs cumulative available N per acre five years post-application, attempting to strike a balance between rates at which impacts on plant diversity would be reasonably unlikely and rates that would promote significant C sequestration. This "recommended" rate would be appropriate for most eligible rangelands (see eligibility discussion below). The "high end" rate is equivalent to 60 lbs cumulative available N per acre five years post-application, allowing for more C sequestration but with some risk of impacting plant diversity. This "high end" rate would be appropriate to situations such as degraded rangelands with few native plant species, vegetation restoration sites (e.g., mines), and perhaps post-fire rangelands, where initial soil N may be lower.

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Table 3. Literature review of organic amendment additions to semi-arid rangelands, sorted by N released at time of plant diversity measurement.

Amendment Type	Study	Mg/ha applied	Amendment N Category	Years between application & measurement	Inorganic N (lbs per ton compost)	Organic N (lbs per ton compost)	Available lbs N released/acre at time of measurement	Plant diversity decrease
non-composted	Pierce et al. 1998[33]	5	Lower N	2	0.34	0.24	0.52	N
non-composted	Pierce et al. 1998[33]	10	Lower N	2	0.34	0.24	1.04	N
non-composted	Pierce et al. 1998[33]	15	Lower N	2	0.34	0.24	1.56	N
non-composted	Pierce et al. 1998[33]	20	Lower N	2	0.34	0.24	2.08	N
non-composted	Pierce et al. 1998[33]	25	Lower N	2	0.34	0.24	2.60	N
non-composted	Pierce et al. 1998[33]	30	Lower N	2	0.34	0.24	3.12	N
non-composted	Pierce et al. 1998[33]	35	Lower N	2	0.34	0.24	3.64	N
non-composted	Pierce et al. 1998[33]	40	Lower N	2	0.34	0.24	4.16	N
non-composted	Sullivan et al. 2006[34]	2.5	Higher N	13	7.48	82.32	17.21	N
compost	Kowaljow et al. 2010[35]	40	Lower N	2	0.48	14.92	18.57	N
compost	Kowaljow et al. 2010[35]	40	Lower N	2	0.96	13.04	22.58	N
compost	Pedrol et al. 2010[36]	20	Lower N	0.5	2.36	43.44	26.65	N
non-composted	Sullivan et al. 2006[34]	5	Higher N	13	7.48	82.32	34.42	N
non-composted	Stavast et al. 2005[37]	12	Higher N	2	2.60	31.60	37.59	Y
compost	Kowaljow et al. 2010[35]	40	Lower N	2	1.06	29.94	38.41	N
compost	Martínez et al. 2003[38]	40	Lower N	3	1.82	33.38	54.82	Y
compost	Kowaljow et al. 2010[35]	40	Lower N	2	2.68	34.32	61.24	N
non-composted	Sullivan et al. 2006[34]	10	Higher N	13	7.48	82.32	68.85	Y
compost	Martínez et al. 2003[38]	80	Lower N	3	1.82	33.38	109.64	Y
non-composted	Sullivan et al. 2006[34]	21	Higher N	13	7.48	82.32	144.58	Y
compost	Ryals and Silver 2013[3]	70	Higher N	3	2.38	35.02	146.72	N*
non-composted	Martínez et al. 2003[38]	40	Higher N	3	4.02	48.98	158.30	Y
non-composted	Fresquez et al. 1990[39]	22.5	Higher N	3	7.38	89.82	163.30	N
compost	Martínez et al. 2003[38]	120	Lower N	3	1.82	33.38	164.46	Y
non-composted	Jurado-Guerra et al. 2013[40]	30	Higher N	2	6.22	75.78	167.89	Y
non-composted	Sullivan et al. 2006[34]	30	Higher N	13	7.48	82.32	206.54	Y
non-composted	Jurado-Guerra et al. 2013[40]	45	Higher N	2	6.22	75.78	251.83	Y
non-composted	Martínez et al. 2003[38]	80	Higher N	3	4.02	48.98	316.60	Y
non-composted	Fresquez et al. 1990[39]	45	Higher N	3	7.38	89.82	326.61	Y
non-composted	Jurado-Guerra et al. 2013[40]	60	Higher N	2	6.22	75.78	335.77	Y
non-composted	Stavast et al. 2005[37]	107	Higher N	2	2.60	31.60	343.17	Y
non-composted	Jurado-Guerra et al. 2013[40]	75	Higher N	2	6.22	75.78	419.72	Y
non-composted	Martínez et al. 2003[38]	120	Higher N	3	4.02	48.98	474.90	Y
non-composted	Jurado-Guerra et al. 2013[40]	90	Higher N	2	6.22	75.78	503.66	Y

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non-composted	Fresquez et al. 1990[39]	90	Higher N	3	7.38	89.82	653.21	Y

*plant diversity data from Ryals et al. *in press* (as communicated by R. Ryals)

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Table 4. Proposed agronomic rates for compost application to rangelands. "Recommended" rates are equivalent to 30 lbs cumulative available N per acre five years post-application and would be an appropriate starting point for most eligible rangelands. "High end" rates are equivalent to 60 lbs cumulative available N per acre five years post-application and would be appropriate in situations where plant diversity impacts are less of a concern (discussed above).

Compost Type	"Recommended" Moist Compost Application Rate (tons/acre)	"Recommended" Equivalent Dry Compost Application Rate (tons/acre)	"High end" Moist Compost Application Rate (tons/acre)	"High end" Equivalent Dry Compost Application Rate (tons/acre)
Higher N (C:N ≤ 11)	5	3.5	10	7.1
Lower N (C:N > 11)	15	9.8	30	19.6

Some types of rangeland are especially sensitive to nutrient addition and/or contain high concentrations of rare and threatened species. For example, impacts on species of conservation concern in serpentine grasslands have occurred at N addition rates that are one-fifth of the "recommended" compost rates identified here[30–32] (Table 4). *All such sensitive areas should be ineligible for compost addition incentives*. Stakeholders including The Nature Conservancy and the California Native Plant Society have prepared maps identifying these areas, which could easily be used to screen proposed projects. The expert group at the second CDFA meeting agreed with the need to avoid adding compost to these sensitive ecosystems. Therefore, additional ecologically-based eligibility exclusions should be considered for rangeland compost application.

Summary of compost application rates for croplands and rangelands

A summary of the recommend rates for compost application to support a CDFA incentive program on soil health is provided in Table 5 below.

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Table 5. Recommendations of the expert group for compost application to agricultural lands distributed by type of agronomic system, C:N ratio and type of farming. The recommended rates do not limit farmers from adding additional compost since these recommended rates have been established on an agronomic and environmental basis to solely support a CDFA healthy soils incentive program. The rates to use for the proposed incentives program are the "equivalent dry compost application rates"(†), which should be converted to corresponding moist compost application rates on a batch-specific basis using moisture data from the compost facility. For rangelands, the lower end of the rate range is an appropriate starting point for most rangelands, while the higher end of the range could be appropriate in situations where plant diversity impacts are less of a concern (discussed above).

System	Management	Crop Type	Compost Type	Moist Compost Application Rate (tons/acre)	Equivalent Dry Compost Application Rate (tons/acre)†
Cropland	Conventional	Annual	Higher N (C:N ≤ 11)	3 – 5	2.2 – 3.6
Cropland	Organic	Annual	Higher N (C:N ≤ 11)	3 – 5	2.2 – 3.6
Cropland	Conventional	Annual	Lower N (C:N > 11)	8	5.3
Cropland	Organic	Annual	Lower N (C:N > 11)	8	5.3
Cropland	Conventional	Tree	Higher N (C:N ≤ 11)	2 – 4	1.5 – 2.9
Cropland	Organic	Tree	Higher N (C:N ≤ 11)	2 – 4	1.5 – 2.9
Cropland	Conventional	Tree	Lower N (C:N > 11)	6 – 8	4.0 – 5.3
Cropland	Organic	Tree	Lower N (C:N > 11)	6 – 8	4.0 – 5.3
Rangeland	--	--	Higher N (C:N ≤ 11)	5(–10)	3.5(–7.1)
Rangeland	--	--	Lower N (C:N > 11)	15(–30)	9.8(–19.6)

Other Considerations

Nitrous oxide (N_2O) emissions. An additional issue that was raised was whether compost application to croplands could cause increases in nitrous oxide (N_2O) emissions. This might be suspected because compost provides an additional organic carbon source for soil microbes, and organic carbon is one of the limiting factors for heterotrophic denitrification, one of the N_2O production pathways in soil. This anaerobic pathway is expected to be a significant contributor to N_2O emissions when soils are relatively saturated (> 80% water-filled pore space) and it may be limited by either carbon or nitrate under those conditions.

Under most other conditions, reactions related to nitrification including ammonia oxidation and nitrifier denitrification are believed to be the dominant contributor to N_2O emissions from California's agricultural soils[14,15]. These reactions are carried out by autotrophs that are not stimulated by organic carbon addition. Finally, all of these N_2O production pathways do tend to be stimulated by addition of ammonium, such that an increase in N_2O emissions may be noted when comparing compost-amended soil to an unamended control because of the ammonium provided by the compost. However, the impact of ammonium

addition via compost would not be expected to be greater than that of addition of an equivalent amount of ammonium via synthetic fertilizer, and these effects can therefore be considered within the "percentage of recommendation" framework outlined above.

Organically-managed croplands. There is considerable variation among organic growers in the use of compost for plant nutrient provision; some growers apply substantial compost to supply a significant percentage of crop nutrient needs, whereas others may apply little to no compost and rely on other organic nutrient sources, such as manure, certain cover crops, and feather meal[10]. It is challenging, therefore, to define a compost application rate that would fit well into the nutrient management system of all organic growers. As such, at the second subcommittee meeting the group agreed that the application rates eligible for cost-share financial incentives could be the same for organic and conventional growers (Table 2), with the understanding that organic growers, in general, may apply greater amounts of compost in total, but are only eligible for a the same cost share incentives as conventional growers.

Phosphorus. For phosphorus-driven eutrophication concerns on rangelands, a site-specific risk factor analysis is an alternative strategy to across-the-board limits on application rates. Similar to the "phosphorus index" approach applied in many states to evaluate risk from phosphorus application to croplands[27], rangeland areas with low soil P that are at a considerable distance from waterways probably would not create significant risk and therefore might base their application rates on other concerns. For areas that do have one or both of these risk factors, a more detailed risk assessment can be conducted[27], and some or all of the risk could be mitigated by adjusting the compost application rate and/or using best management practices (BMPs) such as riparian buffers. Alternatively, potentially problematic areas of the property could simply be avoided if there are other more suitable areas. The American Carbon Registry's Methodology for Compost Additions to Grazed Grasslands (Version 1.0)[28] recommends a site survey by a Qualified Expert (i.e., a Certified Rangeland Manager, NRCS Soil Conservationist or Qualified Extension Agent) before compost is applied to assess this and other risks.

Life cycle concerns. A frequently-raised question is whether the CO_2 emitted in transporting compost to the rangeland site would be greater than the C sequestered as a result of its application. This might be the case if considering only the C sequestered via biological activity on site, which for rangelands is estimated to be approximately 50% of the CO_2 emitted during transport based on a life cycle analysis using data from these northern California rangeland sites[6]. However, this balance depends on the system to which compost is applied and the methods used to make emissions estimates. For example, a California Air Resources Board study of compost application to croplands estimated that transport to the application site would emit 0.008 MT CO_2e per ton of composted feedstock while on-site soil C increases (estimated using biogeochemical process modeling rather than field data) would sequester 0.26 MT CO_2e per ton of composted feedstock, on average[7]. Furthermore, if increased demand for compost created by rangeland application is assumed to be directly responsible for increased diversion of organic waste from landfills and/or manure from slurry ponds into aerobic composting processes, then this practice reduces GHGs due to avoided methane emissions[6] which is 28 times more potent than carbon dioxide. Assessing this claim is beyond the scope of

this report, as there are numerous other drivers of diversion of organic wastes and manures to composting in California, such that it is difficult to estimate the present and potential future contributions of rangeland demand.

Rangeland site assessments. For rangelands, an in-person site assessment by a qualified professional, as stipulated in the American Carbon Registry Protocol[28], is highly recommended in addition to using the agronomic rates. This professional should survey the site for species of conservation concern, identify any potential places where phosphorus transport poses a eutrophication risk, recommend BMPs to mitigate runoff, and assess other resource concerns as appropriate. Comprehensively evaluating a practice's potential effects on all natural resources is a standard NRCS procedure, and, as such, should be part of any Compost Addition to Rangelands Conservation Practice Standard.

Additional considerations for rangelands. First, five of the nine studies in the literature review involved non-composted organic amendments. Nitrogen mineralization is likely to be faster in non-composted than in composted amendments, such that levels of available N may be underestimated for non-composted amendments in Table 3.

Second, nitrogen is not the only soil nutrient that could increase with compost addition, as compost usually contains significant phosphorus, potassium, and other secondary plant nutrients as well. Here, rates were determined based on N release because there are more studies demonstrating N impacts on California grassland plant communities than there are for other nutrients [29]. However, other nutrients and indirect effects may have important consequences over the longer term[41].

Finally, it is important to consider the ecology of California rangeland plant communities when evaluating findings of "no impact" on their diversity. Many rangeland forb species form seed banks and only appear in years that are favorable for them. Any change in soil conditions may alter the degree of favorability of such years for these species, but this alteration may not be detected within the timeframe of most published studies. These dynamics suggest a precautionary approach to practices that could impact California rangeland plant diversity.

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