4.6 CSA Crop Rotation and Soil Fertility

Lecture Outline: CSA Crop Rotation and Soil Fertility

A. Basic Principles and Practices of Crop Rotation

1. The agronomic benefits of crop rotation
   (See Appendix 1: Agronomic and Economic Benefits of Crop Rotation)
   a. Preventive insect pest management – Crop rotation may limit the growth of populations of agricultural pests (including insects, nematodes, and diseases caused by bacteria, viruses, and fungi) through regularly interrupting and replacing crop hosts with different plant species. The use of specific crop and cover crop rotations may also be used to control pests through allelopathy, an interference interaction in which a plant releases into the environment a compound that inhibits or stimulates the growth or development of other organisms.
   b. Reduced weed competition – Carefully designed crop rotations may also serve to outcompete problematic weed species through shading, competition for nutrients and water, and/or allelopathy
   c. Nutrient management
      i. Distribute nutrient demand placed on soil by crops – Different crops place different nutrient demands on the soil. Crops may be rotated to avoid over extraction of soil nutrients in a given area
      ii. Catch crops – Making efficient use of nutrient inputs. Growing crops that access nutrients from different soil horizon depths makes greater use of nutrient inputs by potentially marketable crops. Growing marketable catch crops and cereals/grasses in a cover crop mixture can also prevent nutrient losses/leaching and associated environmental problems.
      iii. Nitrogen fixation – Annual cover crop rotations using nitrogen fixing cover crops may contribute significant amounts of nitrogen to succeeding crops as well as organic matter to the soil
   d. Improving soil quality
      i. Improving soil quality through long rotations – Cover crop rotations using perennial grasses lasting 6 months to one year or more may contribute significantly to organic matter accumulation, stimulate soil biological activity and diversity, and improve soil physical properties. Long-term pasture rotations may allow for the integration of animals into the crop production system, thereby providing an additional source of income while improving soil quality.
      ii. Improving soil quality through short rotations – Well-designed short-term rotations may also be used to create optimal growing conditions for subsequent crops (e.g., potatoes create an optimal soil tilth for carrots)
      iii. Crops requiring significant foot traffic for harvest and maintenance (e.g., strawberries) can be followed in subsequent years with crops requiring little to no foot traffic (e.g., winter squash) to reduce or alleviate soil compaction
   e. Increased crop yields – The rotation effect. Yields of crops grown in rotation are often higher than those grown in monocultures, even when both are supplied with abundant nutrients and water.
   f. Water management improvements – The improvement of soil physical properties through crop rotation and organic matter accumulation may improve water-holding capacity and drainage characteristics

2. Economic benefits of crop rotation
   a. Growing a diversity of crops in a given year spreads out labor needs throughout a season. The diversity of crops reduces the economic risks caused by variations in climate and/or market conditions.
   b. Advanced crop planning where crop rotation is included allows the grower to make the most efficient use of available open ground in a given season and thereby maximize yield in diverse cropping systems
3. Basic practices of crop rotation (see Appendix 2: Ten Basic Practices of Crop Rotation)
   a. Separate in space and time crops that share similar pests and diseases
      i. Rotate the location of annual crops each year. This is especially true for crops in the Solanaceae family (e.g., peppers, eggplants, tomatoes, potatoes, etc.) that share similar diseases.
      ii. In a given season, do not follow one crop with a closely related crop species in the same ground, as pests and diseases are shared by closely related crops
      iii. In a given season, separate as widely as possible the crops known to share similar pests or diseases
   b. When growing a wide diversity of crops, attempt to group crops into blocks according to the following criteria (see Appendix 3: Suggested Crop Groupings for CSA Production Systems)
      i. Similar timing/maturation periods
      ii. Type of crop (i.e., root vs. fruit vs. leaf crop)
      iii. Crops with similar cultural requirements (e.g., irrigation, plastic mulch, dry farmed, planted to moisture crops, etc.)
   c. Follow nitrogen-fixing cover crops and/or legume forage crops (e.g., clover, alfalfa, etc.) with heavy feeding crops (e.g., corn) to take advantage of available nitrogen supply
   d. Follow long-term crop rotations (e.g., 1 year perennial rye rotation or pasture rotations) with disease-sensitive crops such as strawberries
   e. In diverse annual production systems, heavy-feeding crops (i.e., crops with high nutrient demands) should be followed by medium- to light-feeding crops or shallow-rooted crops, followed by deep-rooted crops. (See Appendix 4: Approximate Pounds/Acre of Nutrients Removed by Common Crops.)
   f. Always grow some crops that will produce and leave a large amount of biomass that can be incorporated into the soil to maintain soil organic matter levels
   g. Grow deep-rooted crops (e.g., sunflower, fava beans, etc.) that access nutrients from lower soil horizons, alleviate soil compaction, and fracture the sub-soil, thus promoting water infiltration and root penetration
   h. Use crop sequences known to aid in controlling weeds
   i. Rotate the areas where crops requiring high foot traffic (e.g., carrots) are grown with those requiring little to no traffic (e.g., winter squash)
   j. Use crop sequences known to promote healthy crop growth (e.g., corn followed by onions followed by Brassicaceae crops) and avoid cropping sequences known to promote pests and diseases (e.g., monoculture production generally, peas followed by potatoes specifically)

B. Case Study: Crop Rotation and Soil Fertility Management of the UCSC Farm Fields (1990–2003)

1. Examples of multi-year crop rotation plans
   a. See Appendix 5: UCSC Farm Field 8-Year Crop Rotation Plan
   b. Mapping crop rotation and soil fertility inputs (see Appendix 6: Soil Fertility and Crop Rotation Maps of UCSC Farm Fields)

2. Soil fertility management practices
   a. Compost application rates
      i. 1989–2001: 25 tons/acre on an 8-year rotation schedule
      ii. 2001–present: 5–7 tons/acre/year is applied, principally for phosphorus, potassium (not supplied by cover crops), and additions of organic matter
   b. Cover crops
      i. Equipment used: Tye grain drill (at 6-inch spacing)
      ii. Timing of annual fall sowings: October 15–November 15
      iii. Timing of annual incorporation: March 1–May 1 weather/soil moisture dependent (ideally at full flower)
      iv. Cover crop mixture
      · Bell beans (*Vicia faba*) sown at 75 lbs/acre
      · Oats, Cayuse White (*Avena* spp.) sown at 5–7 lbs/acre
      · Vetches (*Vicia* spp.) sown at 75 lbs/acre
      v. Amount of nitrogen fixed: Approximately 100 lbs/acre
      vi. Experiments with the legume/grass ratios in the cover crop mix (described above) are taking place to attempt to influence mineralization rate of the cover crops to better match the nutrient demands of the subsequent cash crops
   c. Supplemental fertilization
      i. Fertilizer injections of Phytamin 800 through the irrigation system is used on specific heavy-feeding crops (e.g., strawberries, peppers, or recently established perennial crops such as blueberries)
      ii. Examples of application rates of supplemental fertilizers
      · Strawberries: 3 split applications at 14/lbs N/acre
      · Blueberries: 10–15 lbs N/month for 3–4 months

Resources

PRINT RESOURCES

Building Soils for Better Crops. Second Edition, by F. Magdoff and H. Van Es. Sustainable Agriculture Network, Handbook Series Book 4. National Agricultural Library. Beltsville, MD, 2000.

An overview of the management of soil fertility in sustainable farming systems. Covers the basics of soil organic matter management, physical and chemical properties of soil, ecological soil, and crop management. Contains practical and accessible information on crop rotation. See: www.sare.org.

Crop rotation and intercropping strategies for weed management, by Matt Liebman and Elizabeth Dyck. *Ecological Applications* 3(1): 92-122, 1993.

Also available online through UC Sustainable Agriculture Research and Education Program (UC SAREP): www.sarep.ucdavis.edu.

Crop rotation efficiencies and biological diversity in farming systems, by David F. Bezdicek and David Granatstein. *American Journal of Alternative Agriculture* 4(3,4): 111–119, 1989.

Also available online through UC SAREP: www.sarep.ucdavis.edu.

Managing Cover Crops Profitably. Second Edition. Sustainable Agriculture Network. Handbook Series Book 3. Sustainable Agriculture Network. National Agricultural Library. Beltsville, MD, 1998.

Very useful information on the characteristics, costs, seeding rates, and management of different cover crop species. See: www.sare.org.

Michigan Field Crop Ecology. Extension Bulletin E-2646. Michigan State University Extension, 1998.

A well-illustrated 85-page publication covering the soil ecosystem processes managed in agricultural systems (e.g., major nutrient cycles, soil biology, pest and disease management).

The New Organic Grower: A Master's Manual of Tools and Techniques for the Home and Market Gardener, by Elliot Coleman. Chelsea Green Publishing Co. White River Junction, VT, 1995.

An overview of intensive organic production methods on a small scale. Contains chapter on crop rotation planning for diversified vegetable operations.

Organic Vegetable Production, by Abby Seaman (ed.). NRAES-165. NRAES, Cooperative Extension, 2004.

Organic Vegetable Production is the proceedings of a three-day series of meetings held at the New York State Agricultural Experiment Station in Geneva, New York in January 2003. The meetings brought together both university and farmer speakers to share information on management practices. Includes information on managing soil quality, weeds, diseases, and insects (both pest and beneficial). Case studies describe farmer practices related to fertility management, compost, crop rotations, cover crops, mulching, and irrigation. Available from www.nraes.org/publications/nraes165.html.

Overview of Cover Crops and Green Manures, by Preston Sullivan. Fundamentals of Sustainable Agriculture Series. ATTRA – National Sustainable Agriculture Information Service, 2003.

Also available online through ATTRA at: http://attra.ncat.org/attra-pub/covercrop.html; http://www.attra.ncat.org/attra-pub/PDF/covercrop.pdf.

WEB SITES

Alternative Farming Systems Information Center: www.nal.usda.gov/afsic

Technical information on organic farming, sustainable agriculture, and community supported agriculture. Access to National Agricultural Library to research journal articles, abstracts, and to order articles.

ATTRA – Appropriate Technology Transfer for Rural Areas:
www.attra.org

A national sustainable farming information center. Information on sustainable farming production practices, alternative crop and livestock enterprises, and innovative marketing.

Managing Cover Crops Profitably:
www.sare.org/publications/covercrops.htm

The online version of this Sustainable Agriculture Network publication's second edition. Summarizes more than 30 cover crops by region. Explores how and why cover crops work and provides all the information needed to build cover crops into any farming operation. This is the most comprehensive book ever published on the use of cover crops to improve cropping systems and build soil. Also available on CD ROM.

UC Sustainable Agriculture Research and Education Program (UC SAREP):
www.sarep.ucdavis.edu

Sustainable agriculture news, technical information, grant programs, Biologically Integrated Farming Systems program from the University of California.

USDA's Sustainable Agriculture Research and Education Program and the Sustainable Agriculture Network (SARE/SAN):
www.sare.org

The Sustainable Agriculture Research and Education (SARE) program is part of USDA's Cooperative State Research, Education, and Extension Service (CSREES). Managed in partnership with regional land grant hosts, SARE funds projects and conducts outreach designed to improve agricultural systems. The Sustainable Agriculture Network (SAN) is the national outreach arm of the SARE program. SAN publishes a variety of print and electronic resources for farmers, agricultural educators, and consumers. SAN also hosts SANET-MG, a sustainable agriculture listserv with over 600 subscribers from around the globe.

UC Sustainable Agriculture Research and Education Program (UC SAREP) Cover Crop Resource Page:
www.sarep.ucdavis.edu/ccrop

The UC SAREP Cover Crop Database includes more than 5,000 items gleaned from more than 600 separate sources, including journal articles, conference proceedings, standard textbooks, unpublished data, and personal communications from researchers and farmers. The information covers the management and effects of more than 32 species of plants usable as cover crops. More than 400 different cover crop images are also available for online viewing. Geared to the Mediterranean climate of California.

Appendix 1: Agronomic and Economic Benefits of Crop Rotation

1. **Preventive pest management**
   Crop rotation may limit the growth of populations of agricultural pests including insects, nematodes, and diseases caused by bacteria, viruses, and fungi through regular interruption and replacing crop host species with different plant species that do not serve as hosts. The use of specific crop and cover crop rotations may also be used to control pests through allelopathy, an interference interaction in which a plant releases into the environment a compound that inhibits or stimulates the growth or development of other organisms.
2. **Reduced weed competition**
   Carefully designed crop rotations may also serve to outcompete problematic weed species through shading, competition for nutrients and water, and/or allelopathy.
3. **Distribution of nutrient demand placed on soil by crops**
   Different crops place different nutrient demands on the soil.
4. **Making efficient use of nutrient inputs**
   Cropping species that access nutrients from different depths within the soil horizon may make the most efficient use of nutrient inputs. Efficient use of agricultural nutrients may further prevent nutrient losses/leaching and associated environmental pollution.
5. **Nitrogen fixation**
   Annual cover crop rotations using nitrogen-fixing (legume) cover crops may contribute significant amounts of nitrogen to succeeding crops as well as adding organic matter to the soil.
6. **Improving soil quality**
   Cover crop rotations allow soils to remain undisturbed for various periods of time during which the processes of soil aggregation can take place. The use of a perennial grass rotation lasting 6 months to one year or more may significantly contribute to organic matter accumulation, stimulate soil biological activity and diversity, and improve soil physical properties.
7. **Increased crop yields**
   The rotation effect – Yield of crops grown in rotation are often higher than those grown in monocultures, even when both systems are supplied with abundant nutrients and water.
8. **Economic benefits of crop rotation**
   Growing a diversity of crops in a given year spreads out labor needs throughout a season. The diversity of crops reduces the economic risks caused by variations in climate and/or market conditions.

Appendix 2: Ten Basic Practices of Crop Rotation

1. Rotate the location of annual crops each year. This is especially true for crops in the Solanaceae family (e.g., peppers, eggplants, tomatoes, potatoes, etc.).

2. Do not follow one crop with a closely related crop species, as pests and diseases are shared by closely related crops.

3. When growing a wide diversity of crops, attempt to group crops into blocks according to the following criteria:
   a. Plant family
   b. Similar timing/maturation periods
   c. Type of crop (i.e., root vs. fruit vs. leaf crop)
   d. Crops with similar cultural requirements (e.g., irrigation, plastic mulch, dry farmed, planted to moisture crops, etc.)

4. Follow nitrogen-fixing cover crops and/or legume forage crops (e.g., clover, alfalfa) with heavy-feeding crops (e.g., corn) to take advantage of nitrogen supply.

5. Follow long-term crop rotations (e.g., 1-year perennial rye rotation or pasture rotations) with disease-sensitive crops (e.g., strawberries).

6. In diverse annual production systems, heavy-feeding crops (crops with high nutrient demands) should be followed by medium-light or shallow-rooted crops, followed by deep-rooted crops.

7. Always grow some crops that will produce and leave a large amount of residue/biomass that can be incorporated into the soil to help maintain soil organic matter levels.

8. Grow deep-rooted crops (e.g., sunflower, fava beans, etc.) that may access nutrients from lower soil horizons, alleviate soil compaction, and fracture sub-soil, thus promoting water infiltration and subsequent root penetration.

9. Use crop sequences known to aid in controlling weeds.

10. Use crop sequences known to promote healthy crop growth (e.g., corn followed by onions followed by Cole/Brassicaceae crops) and avoid cropping sequences known to promote pests and diseases (e.g., monocultures in general or peas followed by potatoes specifically).

Adapted from Building Soils for Better Crops. Second Edition, by F. Magdoff and H. Van Es. Sustainable Agriculture Network, Handbook Series Book 4. National Agricultural Library. Beltsville, Maryland, 2000.

Appendix 3: Suggested Crop Groupings for CSA Production Systems

1. Group crops in same plant family (e.g., Solanaceae)

2. Group crops with similar timing/maturation periods
   - Separate succession plantings (e.g., lettuce) from single planting/extended harvest crops (e.g., peppers, eggplant, tomatoes, strawberries)
   - Separate single planting/single harvest crops (e.g., hard squash, garlic, potatoes) from other crops in order to manage irrigation

3. Group by "type" of crop (i.e., root vs. fruit vs. leaf crop)

4. Group crops with similar cultural requirements
   - Irrigation
     - Separate drip irrigated from overhead/sprinkler irrigated crops
     - Group crops with similar requirements for frequency of irrigation
   - Plastic mulch vs. bare soil
   - Dry-farmed crops vs. irrigated crops
   - Large-seeded crops planted to moisture (e.g., corn, beans, squash) vs. small-seeded crops requiring irrigation for germination
   - Small-seeded, direct-sown succession plantings (e.g., carrots, beets, salad mix, etc.) grouped together, so you can turn large blocks of ground over to succession planting/sowings as needed

Appendix 4: Crop Removal: Approximate Pounds/Acre of Nutrients Removed by Common Crops

CROP	YIELD	NITROGEN	PHOSPHATE	POTASH	CALCIUM	MAGNESIUM	SULFUR
GRAINS							
Corn	200 bushels	300	120	260	42	30	32
Rice	150 bushels	150	60	160	24	17	18
Soybeans	60 bushels	330	72	144	102	14	27
Wheat	74 bushels	158	54	120	20	18	17
HAY - LEGUMES							
Alfalfa	10 tons	600	140	500	280	50	50
Vetch	5 tons	275	75	225	120	25	25
HAY - GRASSES							
Coastal Bermuda	10 tons	500	120	350	75	45	60
Timothy	5 tons	180	68	220	40	24	14
FRUITS & VEGETABLES							
Apples	21 tons	175	75	320	100	40	40
Cabbage	30 tons	195	72	240	72	30	66
Celery	50 tons	260	110	500	130	40	70
Cucumbers	20 tons	180	60	300	160	40	32
Grapes	10 tons	55	20	100	10	7	11
Lettuce	20 tons	140	46	200	56	14	16
Onions	15 tons	90	41	80	24	9	36
Oranges	30 tons	270	60	270	210	52	30
Peaches	15 tons	116	30	150	101	24	21
Pears	20 tons	118	48	174	102	28	25
Potatoes	25 tons	150	75	250	10	12	8
Spinach	15 tons	150	45	90	36	15	12
Tomatoes	30 tons	120	36	210	15	15	21
Turnips	12 tons	154	34	168	65	12	22
MIXED VEG. AVERAGE		**130**	**54**	**218**	**78**	**21**	**29**

Appendix 5. UCSC CASFS Farm Field 8-Year Crop Rotation Plan (2000)

	SPRING		SUMMER		FALL		WINTER
YEAR 1						perennial rye planted	perennial rye establishes
YEAR 2		perennial rye mowed	perennial rye mowed and irrigated bi-monthly	5 to 10 tons per acre compost applied	rye spaded garlic/onion beds formed pre-irrigated	onions/garlic planted	onions/garlic weeded as needed
YEAR 3	garlic/onions weeded as needed		onions harvested garlic harvested	summer cover planted*	winter cover planted**		
YEAR 4	winter cover tilled in***	brassicas, greens, carrots planted	crops planted, harvested	crops planted, harvested	crops harvested	winter cover crops planted	
YEAR 5	winter cover tilled in***	potatoes planted		potatoes harvested	ground prepared for cover crops	winter cover crops planted	
YEAR 6	winter cover tilled in***	sweet corn, bush beans planted	sweet corn, bush beans planted	sweet corn, bush beans harvested	sweet corn, bush beans harvested	ground prepared winter cover planted	
YEAR 7	winter cover tilled in***	pumpkin, winter squash planted			pumpkin, winter squash harvested	ground prepared winter cover planted	
YEAR 8	winter cover tilled in***	misc. crops planted****	summer covers planted as needed		ground prepared for perennial rye	perennial rye planted	

*summer covers include: annual buckwheat, sudan grass, sordan grass, and vetch

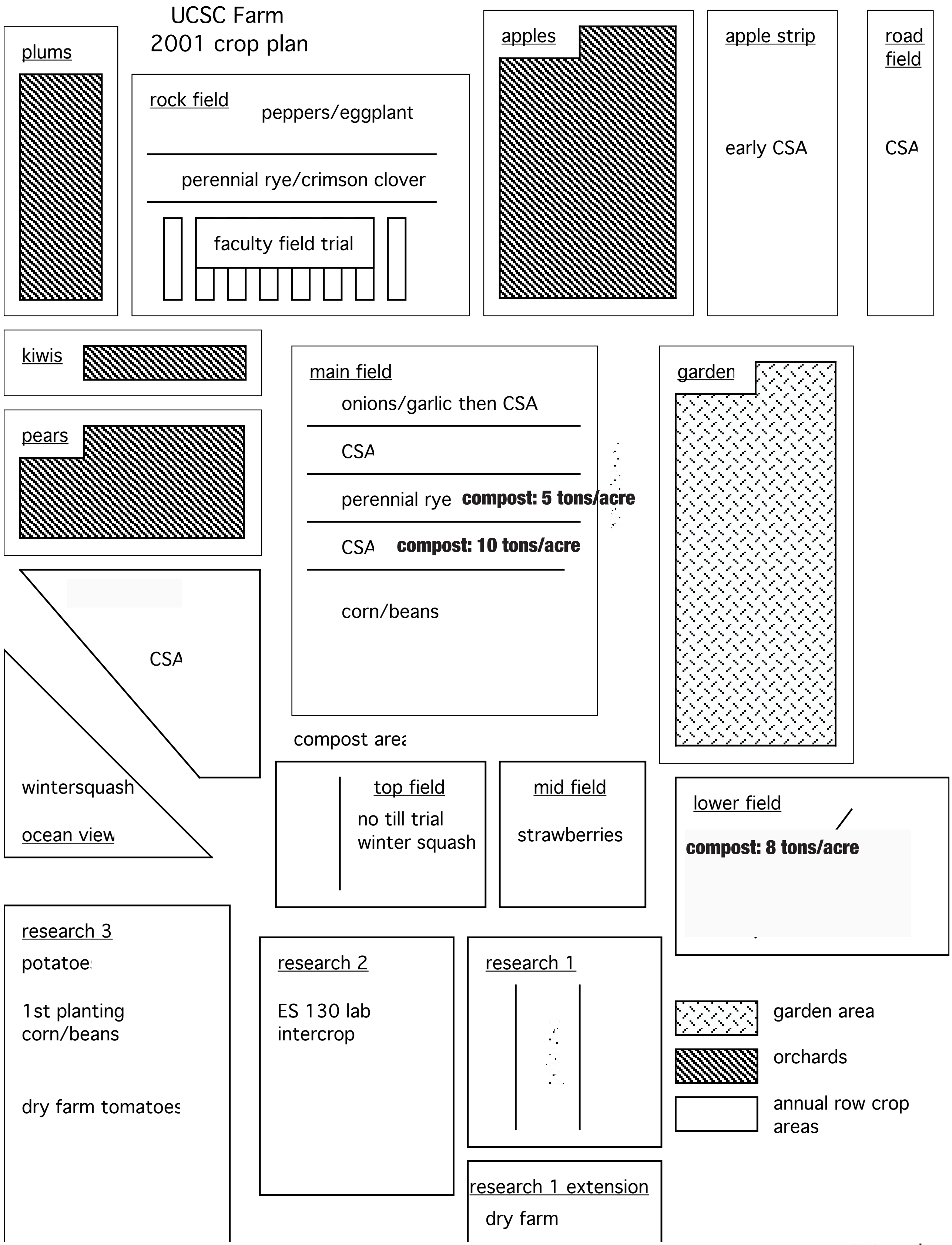
**winter covers include: vetch, bell beans, oats and peas

***spring tillage/incorporation of cover crop residue typically done with a mechanical spader

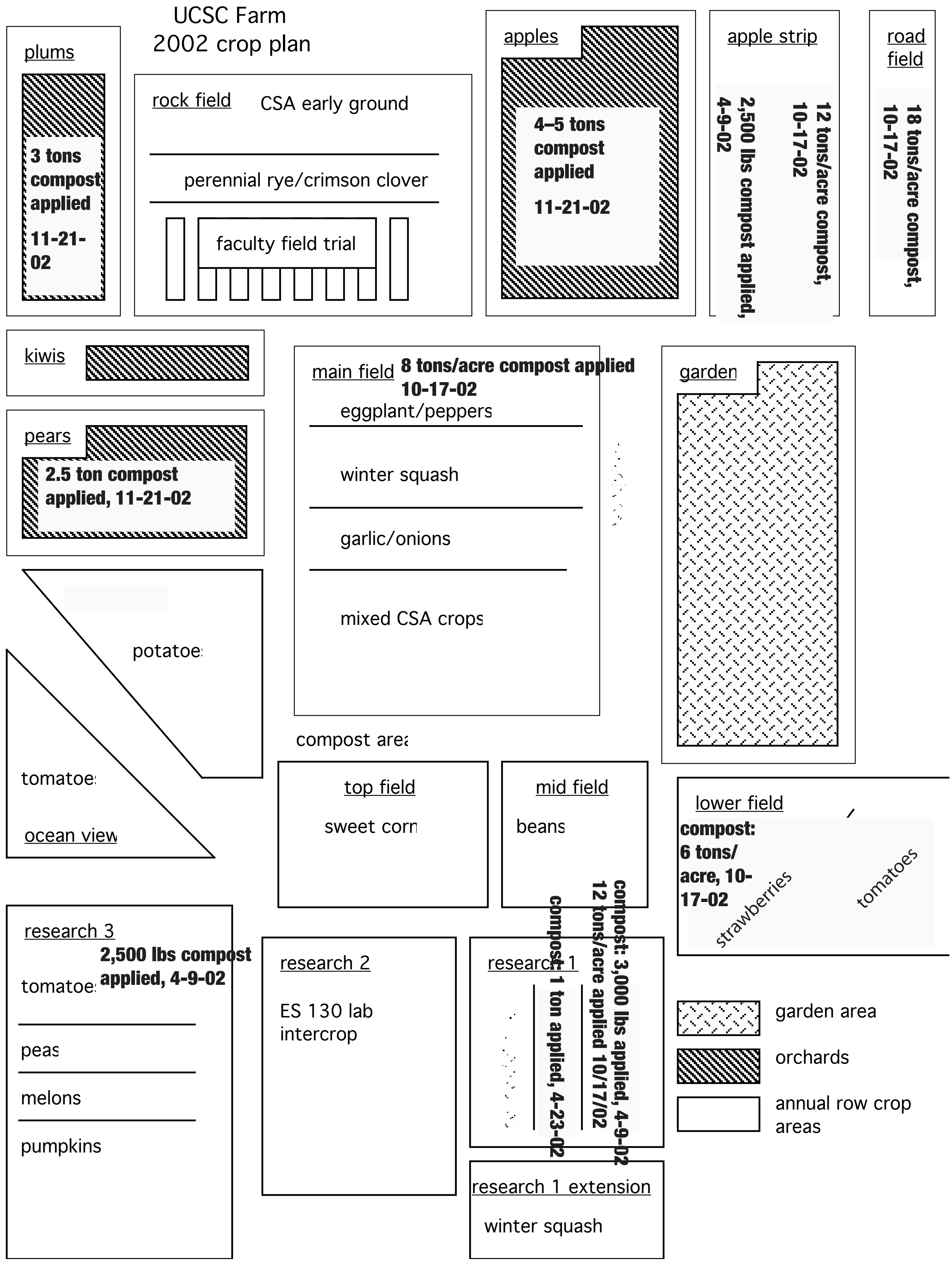
****misc crops include: cucumbers, summer squash, peppers, eggplant, brassicas, basil, misc. herbs, flowers

Note: strawberries and dry-farmed tomatoes are fit into this rotation as conditions warrant

Appendix 6. Soil Fertility and Crop Rotation Maps of UCSC Farm Fields (2001)



Appendix 6 (cont'd). Soil Fertility and Crop Rotation Maps of UCSC Farm Field (2002)



Appendix 6 (cont'd). Soil Fertility and Crop Rotation Maps of UCSC Farm Field (2003)