DRAINAGE REUSE GRANT PROGRAM
GRANT APPLICATION PACKET, 2014 SOLICITATION

Grant Application Checklist *The following information is required to be submitted in proposal applications.*	
	ATTACHMENT 1 *Organizational, Financial, and Legal Information*
☑	Part I: Application Cover Sheet
☑	Part II: Applicant's Representatives
☑	Part III: Summary of Project Costs
☑	Part IV: Authorizing Resolution
	ATTACHMENT 2 *Project Proposal and Task Breakdown*
☑	Project Proposal
	ATTACHMENT 3 *Eligibility Requirements*
☑	Eligibility Checklist
☐	Required Documentation (if applicable)

Attachment 1, Part I – Application Cover Sheet

Application for a grant under § 78645 of the Safe, Clean, Reliable Water Supply Act of 1996

The California State University, Fresno Foundation
(Exact legal name of local entity applying for the grant)

Of 4910 N. Chestnut Avenue
(Mailing address of local entity)

Fresno, CA 93726-1852

Of the County of Fresno, State of California, does hereby apply to the California Department of Water Resources for a grant in the amount of $258,987.

For the following project under the Drainage Reuse Grant Program of the Safe, Clean, Reliable Water Supply Act of 1996:

Investigation of halophyte Salsola soda as an alternative salt-tolerant crop for phyto-management of salt-affected soils and waters high in boron and selenium
(Specify project title)

By _____ Date _____
(Signature of authorized representative)

Thomas McClanahan, Ph.D. Associate Vice President
(Print or type name of authorized representative) *(Title)*

Telephone 559-278-0857 E-mail orsp@csufresno.edu

Brief Proposal Description:

In the West side soils of Central California the presence of natural-occurring salts including selenium (Se) and boron (B), results in the production of poor quality drainage waters that must be sustainably managed and disposed or reused on alternative crops. Identifying new alternative crops (e.g., Salsola soda L., 'agretti') that are salt and B tolerant and possess the ability to extract/volatilize Se while irrigated with such drainage waters, is one primary objective of this study . The second objective is to evaluate the ability of a mesocosm wetland irrigation system comprised of 'agretti' plants to extract Se and B from circulating saline drainage water containing Se and B. In both studies, we will study the mechanisms of Se, B, Na, and Cl uptake, translocation and localization within 'agretti' grown under two different growing conditions. Within the soil profile of the planted "agretti', salt movement will be monitored with EM 38 remote sensing technology as affected by drainage water drip-applied at different rates. Lastly, we will evaluate potential market demand for 'agretti' as an alternative vegetable product grown with typical drainage water from the west side of the San Joaquin Valley.

Attachment 1, Part II – Applicant's Representatives

Project Name Investigation of halophyte Salsola soda as an alternative salt-tolerant crop for phyto-management of salt-affected soils and waters high in boron and selenium

Primary Project Contact

Name Maral Kismetian Title Grants Analyst

Address 4910 N. Chestnut Ave, Fresno, CA 93726

Telephone 559-278-0840 FAX 559-278-0992

E-mail orsp@csufresno.edu

Alternate Project Contact

Name Gary S. Bañuelos Title Senior USDA Scientist

Address 9611 S. Riverbend Ave, Parlier CA 93648

Telephone 559-596-2885 FAX 559-596-2851

E-mail gary.banuelos@ars.usda.gov

Alternate Project Contact (If Applicable)

Name David Zoldoske Title Director of Center for Irrigation Technology

Address 5370 N. Chestnut Ave M/S OF 18, Fresno CA 93740

Telephone 559-278-2066 FAX 559-278-6033

E-mail davidzo@csufresno.edu

Type of Organization: University

(city, county, water district, university, etc.)

Attach a copy of the applicant's charter and the names and titles of its officers.

Attachment I, Part III – Summary of Project Costs

Provide a summary of the financing information about the proposed project, including cost share (if applicable).

		% of Total Cost
Total Cost of Project:	$339,987	
Amount Requested (CWC §78645):	$258,987	76
Amount of Cost Share[1]:	$	
Amount of Federal Contribution:	$81,000	24
In-kind Contributions:	$	
Amount to Funded by Others Sources: (Describe below in table.)	$	

Sources of funds from partner agencies for this project, if applicable:

Amount	**Name of Source**	**Status of Funds[2]**
$		
$		
$		
$		
$		
Total: $		

Additional explanation, if necessary:

Notes:

1. No cost share is required; however, grantees are required to show cost share (e.g., federal, local, or other funds) if an awarded project costs more than the grant amount.
2. Identify the current status of funds: available, planned/budgeted, awarded or pending.

Attachment I, Part IV – Authorizing Resolution

Include a resolution adopted by the applicant's governing body authorizing the application for a grant under this program and designating a representative to sign the application. Note that the authorized representative may not be a consultant or subcontractor. If the resolution cannot be signed by the authorized applicant prior to the application due date, indicate in the proposal document when a signed resolution will be received by DWR. Following is a suggested format.

Resolution No._____

Resolved by the _____
(Governing body, city council, or other)

of the _____
(Name of applicant)

that pursuant to all of the terms and provisions of the Safe, Clean, Reliable Water Supply Act of 1996, application by this

_____ be made to the California Department of
("Agency,", "city", "county", or other)

Water Resources to obtain a grant for _____.
(Project title)

The _____ of the
(Presiding officer, president, city manager, or other official)

_____ is hereby authorized and directed to
("Agency", "city", "county", or other)

prepare the necessary date, make investigations, sign, and file such application with the California Department of Water Resources.

Passed and adopted at a regular meeting of the _____
(Board of Directors, Supervisors, etc.)

of the _____
(Name of applicant)

on _____.
(Date)

Attachment 2 – Project Proposal and Task Breakdown

Applicants are required to submit a project proposal with a detailed task breakdown to complete the Drainage Reuse Grant Program grant application. The proposal should provide detailed description, discussion, and documentation for each of the proposal sections listed below. The proposal should describe the tasks that will be undertaken to implement the project and include a budget and schedule that support and are consistent with the identified tasks.

The level of detail must be sufficient to allow reviewers to understand the level of effort of the work being performed and to relate the proposed work to the budget so that the cost estimates can be substantiated. Page limits and character limits are not specified. The applicant should determine the level of detail required to convey how the proposed project meets the objectives and requirements outlined in the Guidelines/PSP.

The project proposal must include the following items, with at least as much detail as specified in the descriptions below.

1. Title of Project

Provide the title of the project. The title must be descriptive of the technologies proposed and provide an idea of what the project is meant to achieve.

2. Principal Investigator/Cooperator(s) and Project Management

Provide the name, contact information, and description of qualifications of the following persons associated with the project. Roles of key personnel must be clearly defined. Key personnel associated with the project must have sufficient expertise to complete the project, and evidence of competence in the proposed area of work must be provided.

- Project Director: Responsible for executing the grant agreement and any amendments and approving invoices for the applicant. Persons that are subcontractors to be paid with the grant funds cannot be listed as the Project Director.
- Project Manager: Day-to-day contact from the applicant, agency, or organization.
- Principal Investigator(s): Person(s) performing the majority of the research associated with this project.
- Other Cooperators: Cooperating individuals and agencies, including consultants, who will be participating in the implementation of the project.

Information for other key personnel associated with the project may also be provided, if applicable. Qualifications may be enhanced through partnerships with other institutions; these relationships with other institutions should be clearly defined and described.

Discussion and evidence of institutional capacity to successfully complete the project should be provided in this section. The discussion should show that proposed personnel, facilities, and equipment is adequate for successfully completing the project.

Based on the key personnel described in this section, proposals should include a clear plan for project management that includes the following components:

- Adequate time allocation for attainment of objectives and delivery of products.
- Maintenance of partnerships and collaborations.
- A strategy to enhance communication, data sharing, and reporting among members of the project team.

Discussion of the project management plan may reference other areas of the proposal as needed. The development of the project management plan should consider the qualifications of key personnel and should incorporate how involved personnel will achieve the project management components above.

3. Scope of Work and Project Description

Provide a scope of work that briefly summarizes the project activities and tasks that will be implemented to achieve proposed outcomes.

Provide a project description that explains the work to be performed and an overview of deliverables for assessing progress and accomplishments. A complete project description should be concise and include the following information:

- A brief explanation of the goals and objectives, or purpose and need, for the project.
- Description of the components of the project that will be funded by DWR.
- If the project constituents a phase of a larger, multi-phase project, include a discussion of how the phase of work supported by DWR funds can operate or be functional without implementation of other phases of work.
- A description of existing contracts, Memorandums of Understanding, Joint Powers Authorities, or other formal agreements with project partners, if applicable.
- A description of the project location including overlying jurisdiction (city, county, State, or federal land), assessor parcel numbers, property addresses, and the latitude/longitude of the project site. It is suggested to include a project map that shows the project's geographical location and the boundaries of the work.

4. Project Objectives and Program Priorities

Project goals and objectives should be clearly described, adequately developed, and appropriate to help achieve the stated program objectives. When possible, quantifiable objectives should be proposed. Objectives may be presented in a tabular or bulleted format to aid in the review and presentation of the information.

The proposal should identify if the proposed project meets any of the stated program priorities and to what extent they are met. Describe and provide sufficient documentation to support how the project meets one or more of the program priorities stated in the Guidelines/PSP.

The proposed research should fill knowledge gaps that are critical and/or valuable to the development of practices and programs to address identified drainage issues. The proposal

should include a discussion about how the proposed project will help fill these knowledge gaps and to what extent the research will increase the understanding of the identified problems.

5. Task Breakdown

The task breakdown should contain descriptions of all of the tasks necessary to complete the proposed project. The descriptions must contain enough detail to sufficiently explain all the work necessary to complete each task, to demonstrate that the tasks are ready for implementation, to prove that there is a high expectation of successful implementation, and to show that the tasks are consistent with the project schedule and budget. Project tasks may be broken into subtasks for additional clarification of the project components. The task breakdown shall include, at a minimum, the following elements:

- Description of the tasks and subtasks required to complete the project.
- Current status of each task.
- Identification of the budget and costs associated with each task. Proposed costs should be detailed and specific and should be reasonable for the proposed work. The narrative accompanying the task budgets should describe how the costs were developed and should include appropriate and complete documentation of proposed costs and billing rates.
- Schedule for implementing each task, including the start and end date for each task. Potential foreseeable interruptions to the schedule should be identified.
- Development of performance measures for appropriate tasks.
- The expected results and outcomes of the project based on the proposed tasks. The expected outcomes should be clearly stated, measurable, appropriate, and achievable within the project constraints.
- Summary of deliverables and reporting tasks, including quarterly progress reports, invoices, a final report, and a post-completion report.

6. Materials, Methods, and Scientific Merit

The proposed approach, procedures, and methods used should be innovative for the research field, original ideas, clearly defined, suitable for the proposed research, and feasible to accomplish within the project constraints (budget, schedule, project team, etc.). Equipment and materials for the proposed project should be identified and described. Obvious alternatives to the proposed equipment and materials must be addressed and justification of chosen materials provided where necessary. The proposal may include a brief description of supporting studies, data, and resources for the project to ensure implementation of the proposal is based on sound scientific and technical principles.

7. Schedule

Provide a schedule for implementation of the project showing the sequence of tasks and timing. The schedule should be detailed and specific. The schedule must show the start and end dates as well as milestones for each task and should be formatted in a horizontal bar or Gantt chart. The schedule should also illustrate dependencies on preceding tasks by showing appropriate linkages. The schedule must be consistent with the task breakdown and the budget. Time

required for compliance with CEQA, NEPA, and other environmental laws should be included in the schedule. An assumed end date of the grant agreement will not be established by DWR, instead applicants must include a reasonable estimate of the end date, based on their project, including time for any final reports and invoicing. Dates for the submission of quarterly progress reports, a final report, and post-completion report should be included. Assume a realistic start date for your proposed project no sooner than June 2015, and anticipate a maximum 2-year performance period. The schedule must indicate readiness to start the project when funding becomes available.

8. Budget

The budget should include a narrative and a tabular summary of project costs. This section of the proposal should serve as a budget summary section, while the task breakdown should include detailed explanation of the task item costs and documentation of costs and billing rates.

The tabular cost estimate should be organized by task breakdown and should indicate a funding source for the costs attributed to each task. Subtasks and their relative costs should also be included, if applicable. Consistency with the work items shown in the task breakdown should be apparent. The funding source breakdown included in the budget table should indicate costs from the following types of sources: grant amount requested, cost share (if applicable), federal contribution, in-kind contributions, and other contributions. A column indicating total project cost should also be included.

The grantee will present the budget summary tables in a way that best conveys the project costs. The narrative that accompanies the budget tables should provide an overview of the budget and a description of any significant components of the budget that require explanation.

9. Deliverables

Mandatory grant reporting tasks include the submittal of quarterly progress reports, invoices, a final report, and a post-completion report. Other additional deliverables may be applicable to the project, including technical studies, technical memorandums, and other documents useful for reporting the progress of the project. Provide a discussion of proposed project deliverables, proposed timelines for the deliverables (the schedule may be referenced), and other deliverables if appropriate to the project.

Attachment 3 – Eligibility Requirements

Certain applicants and project types require submittal of eligibility documentation. The Eligibility Checklist below may be used as a tool to help determine whether an applicant or a project requires completion and submittal of eligibility documentation. **If documentation is required to prove eligibility for any of the items listed, the documentation must be provided in the grant application.** Some documentation may require explanation or a narrative so as to provide sufficient information for DWR staff to determine if eligibility is met. If the criterion applies to the grant applicant, grant applicants should include a narrative for each of the eligibility requirements below. If DWR determines that the applicant does not have the authority to enter into a grant agreement with the State, the applicant will not be eligible for funding and the application will not be reviewed.

Eligibility Checklist		
Applicable?		
Yes	**No**	**Eligibility Criteria**
Local Agency Certification		
☑	☐	1) Local Agency: The applicant must provide a written statement (and additional information if noted) containing the appropriate information outlined below: - Is the applicant a local agency as defined in CA Water Code §78640(b)? - What is the statutory or other legal authority under which the applicant was formed and is authorized to operate? - Does the applicant have legal authority to enter into a grant agreement with the State of California? - Describe any legal agreements among partner agencies and/or organizations that ensure performance of the proposal and tracking of funds.
☐	☐	2) Basin Plan: Is each project consistent with a Regional Water Quality Control Plan (Basin Plan)?
Urban Water Suppliers		
☐	☐	3) Urban Water Suppliers: List the urban water suppliers that will receive funding from the proposed grant. Please provide the agency name, a contact phone number and an e-mail address. Those listed must submit self-certification of compliance with CWC §525 *et seq*. and AB 1420 (links to appropriate forms in Appendix A).
☐	☐	4) Urban Water Suppliers: Have all of the urban water suppliers listed in #3 above submitted complete Urban Water Management Plans (UWMPs) to DWR? Have those plans been verified as complete by DWR? If not, explain and provide the anticipated date for having a complete UWMP.
Groundwater Projects/Users		
☐	☐	5) Groundwater Projects: Does the proposal include any groundwater projects or other projects that directly affect groundwater levels or quality? If so, provide the name(s) of the project(s) and list the agency(ies) that will implement the project(s).
☐	☐	6) Groundwater Projects: For the agency(ies) listed in #5 above, how has the agency complied with CWC §10753 regarding Groundwater Management Plans (GWMPs)?
☐	☐	7) Groundwater Users: List the groundwater users that will receive funding from the proposed grant. Please provide the agency/organization name, a contact phone number, and an e-mail address. If there are none, please indicate so and skip to #9.
☐	☐	8) Groundwater Users: Have all of the groundwater users, listed in #7 above met the requirements of DWR's CASGEM Program? http://www.water.ca.gov/groundwater/casgem/ If not, explain and provide the anticipated date for meeting the requirements.
Agricultural Water Suppliers		
☐	☐	9) Agricultural Water Suppliers: List the agricultural water suppliers that will receive funding from the proposed grant. Please provide the agency/organization name, a contact phone number and e-mail address. If there are none, please indicate so and go to #11.
☐	☐	10) Agricultural Water Suppliers: Have all of the agricultural water suppliers, listed in #9 above, submitted complete Agricultural Water Management Plans (AWMPs) to DWR? Have those plans been verified as complete by DWR? If the plans have not been submitted, please indicate the anticipated submittal date.
Surface Water Diverters		
☐	☐	11) Surface Water Diverters: List the surface water diverters that will receive funding from the proposed grant. Please provide the agency/organization name, a contact phone number, and an e-mail address. If there are none, please indicate so.
☐	☐	12) Surface Water Diverters: Have all of the surface water diverters, listed in #11 above, submitted surface water diversion reports to the State Water Resources Control Board in compliance with requirements outlined in Part 5.1 (commencing with §5100) of Division 2 of the CWC? If not, explain and provide the anticipated date for meeting the requirements.

The following text provides additional explanation of some of the eligibility requirements listed in the checklist.

All Applicants

- **Local Agency.** An eligible grant applicant must be a local agency, as defined by the CA Water Code §78640(b). As defined in the code, "local agency" or "agency" means any city, county, district, joint powers authority, or other political subdivision of the state involved with water management. As a political subdivision of the state, public universities, including the University of California, are considered to be a local agencies for this grant program.
- **Consistency with Regional Water Quality Control Plan (Basin Plan).** Projects should be consistent with the area Basin Plan. This means that all projects must not contradict the goals and intentions of the Basin Plan, and must support the beneficial uses of water prescribed in the plan.

Urban Water Suppliers

- **Urban Water Management Planning Act (UWMPA) Compliance.** Water suppliers who were required by the UWMPA (CWC §10610 et seq.) to submit an Urban Water Management Plan (UWMP) to DWR must have submitted a complete UWMP to be eligible for State funding. Applicants and project proponents that are urban water suppliers and have projects that would receive funding through the Drainage Reuse Grant Program must have a 2010 UWMP that has been verified as complete by DWR before a grant agreement will be executed.
- **Best Management Practice (BMP) Compliance.** Assembly Bill (AB) 1420 (Stats. 2007, Ch. 628) conditions the receipt of a water management grant or loan by urban water suppliers upon the implementation of water demand management measures described in CWC §10631. DWR has determined that implementation of the California Urban Water Conservation Council (CUWCC) BMPs will fulfill the requirements of AB 1420. An urban water supplier may be eligible for a water management grant or loan if the urban water supplier demonstrates that BMPs have been implemented or scheduled, or are in the process of being implemented or scheduled. Urban water suppliers applying to use grant funds for implementation of BMPs must ensure they have submitted all the necessary information. Therefore, urban water suppliers who are applicants or project proponents in a grant application must supply additional information via a self-certification form. A link to the self-certification form is provided in Appendix A. ***The self-certification form must be signed and submitted with the grant application to be eligible for funding.***
- **Water Meter Compliance.** CWC §529.5 requires any urban water supplier applying for State grant funds for wastewater treatment projects, water use efficiency projects, drinking water treatment projects, or for a permit for a new or expanded water supply, shall demonstrate that they meet the water meter requirements in CWC §525 et seq. Water meter requirements apply to State Water Project contractors, Central Valley Project contractors, local, community, and private water suppliers. Grant applicants must complete a self-certification form to certify that water meter compliance requirements are met. A link to the self-certification form is provided in Appendix A. ***The self-certification form must be signed and submitted with the grant application to be eligible for funding.***

Groundwater Projects Requiring Monitoring or Groundwater Users

- **California Statewide Groundwater Elevation Monitoring (CASGEM) Compliance.** CWC §10920 *et seq.* establishes a groundwater monitoring program designed to monitor and report groundwater elevations in all or part of a basin or subbasin. Information on the requirements of the CASGEM Program can be found here: http://www.water.ca.gov/groundwater/casgem/. The CASGEM requirements also limit counties' and various entities' (CWC §10927.(a)-(d), inclusive) ability to receive State grants or loans in the event that DWR is required to perform groundwater elevation monitoring functions pursuant to CWC §10933.5. Applicants and project proponents that are groundwater users must meet the reporting requirements of DWR's CASGEM program.
- **Groundwater Management Plan (GWMP) Compliance.** For groundwater projects or for other projects that directly affect groundwater levels or quality, ***the applicant or the project proponent responsible for such projects must self-certify*** that either:
  - They have prepared and implemented a GWMP in compliance with CWC §10753.7;
  - They participate or consent to be subject to a GWMP, basin-wide management plan, or other IRWM program or plan that meets the requirements of CWC §10753.7(a);
  - The proposal includes development of a GWMP that meets the requirements of CWC §10753.7 and will be completed within one year of the grant application submittal date; or
  - They conform to the requirements of an adjudication of water rights in the subject groundwater basin.

Agricultural Water Suppliers

- **Agricultural Water Management Plan (AWMP) Compliance.** Beginning July 1, 2013, an agricultural water supplier is not eligible for a water grant or loan awarded or administered by the State unless the supplier complies with Senate Bill (SB) x7-7 water conservation requirements outlined in CWC Division 6 Part 2.55 (commencing with §10608). Applicants and project proponents that are agricultural water suppliers must prepare and adopt an AWMP and comply with submission requirements. Specific requirements for Agricultural Water Management Planning are described in CWC Division 6 Part 2.8 (§10800). A link to the compliance requirements of SBx7-7 is provided in Appendix A.

Surface Water Diverters

- **Surface Water Diversion Reporting Compliance.** Beginning January 1, 2012, a diverter of surface water is not eligible for a water grant or loan awarded or administered by the State unless it complies with surface water diversion reporting requirements outlined in CWC Division 2 Part 5.1 (commencing with §5100). Applicants and project proponents that are surface water diverters must submit surface water diversion reports to the State Water Resources Control Board (SWRCB); SWRCB is the responsible entity for tracking the diversion reporting requirement. DWR will confer with SWRCB to determine eligibility of applicants for this provision; *no additional material applicants is needed for approval.*

Research and Sponsored Programs

The Corporation will administer grants and contracts on behalf of the University under the following conditions:

1. Grant and contract activity shall include research, public service, and educationally related project proposals and awards involving federal, state, municipal, or county agencies, public or private corporations, private foundations, and/or individuals. When such grant or contract provides for direct funding, use of University facilities or resources, and/or endorsement by the University, then approval as herein described is required.

2. All applicable laws, regulations, rules, policies, and practices shall be satisfied prior to acceptance of the grant or contract issue.

3. Grant and contract proposals shall be reviewed by the project director's department chair, or organizational unit director, as appropriate.

4. The Associate Vice President for Research and Sponsored Programs shall administer the submission and approval of grants and contracts. It shall be the responsibility of the California State University, Fresno Research and Sponsored Programs Office to: ensure that appropriate project clearance(s) and approval(s) are obtained from California State University, Fresno organizational units which might be affected thereby prior to final approval and submission of a proposal), in collaboration with the project director involved; assume responsibility for negotiating any terms and conditions that differ substantially from those initially proposed; and keep all University units affected fully informed as to these negotiations.

5. All grants or contracts are to be accepted in the name of the Foundation, whereupon the Foundation business office shall contact individuals and/or organizational units affected by the award.

6. The Secretary of the Foundation, the Chief Financial Officer of California State University, Fresno or his or her designee, the Director of Foundation Financial Services, the Executive Director of the Foundation, and the Associate Vice President for Research and Sponsored Programs of California State University, Fresno, any two acting together, are hereby authorized to execute any contracts or subsequent amendments, with any governmental or non-governmental agencies or organizations as may be necessary in order to carry out the purposes referenced in this resolution, and that any prior resolutions in conflict herewith are hereby superseded.

Approved by the California State University, Fresno Foundation Board of Governors on June 4, 2009.

Drainage Reuse Grant Program

funded by Proposition 204

Application package

Submitted to:

California Department of Water Resources
Integrated Regional Water Management
South Central Region Office
3374 E. Shields Avenue
Fresno, CA 93726
Attn: Maggie Dutton

"Investigation of halophyte Salsola soda as an alternative salt-tolerant crop for phyto-management of salt-affected soils and waters high in boron and selenium"

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1. Title of the Project:

Investigation of halophyte *Salsola soda* as an alternative salt-tolerant crop for phyto-management of salt-affected soils and waters high in boron and selenium.

2. Principal Investigator/Cooperator(s) and Project Management

Project Director: Dr. David Zoldoske

Contact information:

California State University Fresno

Center for Irrigation Technology

Fresno, CA 93740

Phone: (559) 278-2066

Email: davidzo@csufresno.edu

Description of qualifications:

Dr. Zoldoske is the Director of the Center for Irrigation Technology at California State University Fresno. Dr. Zoldoske's work has focused on agricultural resource stewardship issues including the nexus between water, energy and air quality. He has provided program director leadership to numerous successful large-scale farming, resource agency and water industry collaborative activities over the last 30 years. He has over 30 years of experience in irrigation and water issues, and manages staff of 20 researchers, technicians, and program managers. Dr. Zoldoske has authored or co-authored over 100 articles on irrigation and water technology. See Appendix A for his CV.

Role as project director:

Dr. Zoldoske will be responsible for ensuring that each phase of the project is carried out on time and he will be responsible for executing the grant agreement and any amendments and approving invoices. Approximately 1% of his time will be dedicated to the project.

Project Manager: Dr. Gary Bañuelos

Contact information:

9611 S. Riverbend Ave.

Parlier, CA 93648

Phone: (559) 596-2880
E-mail: gary.banuelos@ars.usda.gov

Description of qualifications:

Dr. Bañuelos is a Plant and Soil Scientist at the USDA-ARS-Water Management Research Laboratory in Parlier, CA and an adjunct professor at California State University Fresno. Dr. Bañuelos obtained his Ph.D. in Plant Nutrition and Agriculture in 1987 at the Hohenheim University in Germany. He has studied in the area of Plant Nutrition/Agriculture in both the United States and Germany, and has conducted field research for over 25 years on the use of poor quality water on alternative crops and has extensively researched and studied phytoremediation, an innovative, environmentally friendly green technology to clean up contaminated environments using plants and microbes. His integrated approach to field phytoremediation involves more than just the selection of alternative crops, but also considers crop rotation, irrigation and drainage management, product utilization (e.g., biofuel, animal feed, and biofortification), economic feasibility, and grower and public acceptance. Dr. Bañuelos has written over 150 peer-reviewed publications and has edited four books. He is nationally and internationally recognized for identifying and developing cropping systems for poor quality soils and waters. Approximately 20% of his time will be dedicated to this project. See Appendix A for his CV.

Role as project manager:

Dr. Bañuelos will be the day-to-day contact for the project and he will be responsible for supervising all research activities performed by his research team at USDA-ARS in Parlier, including the activities performed by Dr. Tiziana Centofanti. Dr. Bañuelos will coordinate and manage the field operations with his research-team at the USDA, research faculty, and workers at Red Rock Ranch (RRR), and he will coordinate all activities between principal investigators and cooperators at Fresno State, UC Berkeley, and Red Rock Ranch. Dr. Bañuelos will supervise and coordinate all activities carried out by Mr. Perez, Mr. King, Dr. Centofanti, and Dr. Zhu, including reviewing of quarterly, final and post-completion reports, and scientific publications produced by Dr. Centofanti and Dr. Zhu.

Principal Investigators:

1. Dr. Tiziana Centofanti

Contact information:

Dr. Tiziana Centofanti

California State University Fresno

Center for Irrigation Technology

Fresno, CA 93740

Phone: (559) 596-2885

Email: tcentofanti@csufresno.edu

Description of qualifications:

Dr. Tiziana Centofanti is a Plant and Soil Scientist and is currently a senior research associate at Center for Irrigation Technology, CSU Fresno and has been working closely with Dr. Bañuelos since October 2012. She earned a Ph.D. in Plant Sciences at the Swiss Federal Institute of Technology Zurich, Switzerland. She has expertise in plant metal tolerance, eco-physiology and ecological biochemistry of plants in relation to environmental stresses. She has 10 + years of research experience at different universities in Europe and in the United States. Over this period she has co-led and executed numerous collaborative research projects on food-chain transfer of pollutants, ecological restoration of degraded environments, and development of green technologies for the bioremediation of soil and water.

Dr. Centofanti has mentored and supervised undergraduate and graduate students, as well as summer high school interns. She has published extensively and has presented invited seminars in international, national and regional conferences and at different universities and research institutes. Dr. Centofanti initiated the idea of using the halophyte *Salsola soda* as alternative crop for the saline soil of the San Joaquin Valley. In the summer 2014, she evaluated the plant's performance on SJV soils irrigated with saline water and she and Dr. Bañuelos have recently submitted a publication of this study to the Journal of Environmental Management. See Appendix A for her CV and Appendix B for a copy of submitted manuscript.

Role as principal investigator:

Dr. Centofanti will be responsible of conducting and supervising all field and laboratory activities (see section 5) associated with plant and soil monitoring, sampling and analyses, including analysis of antioxidants in shoot tissue, and root and soil mapping of the soil profile in the field micro-plot study. Dr. Centofanti will supervise the daily activities of the undergraduate student and EM 38 technician from CSU Fresno (Mr. King and Mr. Thao) who will be hired part-time to help in the project. Dr. Centofanti will be helping Dr. Zhu with the set-up of the wetland mesocosm system at UC Berkeley, and with *'agretti'* seeding and transplanting into the wetland system. Dr. Centofanti will meet regularly (see section 5 and 7) with Dr. Zhu to discuss progress, issues, and development of the project. Dr. Centofanti will write the quarterly, final and post-completion reports and scientific articles and present the work at local seminars and at national scientific conferences. In addition, Dr. Centofanti will assist Mr. Murugesan in the preparation and conduction of the economic experimental trials to analyze consumer's preferences and attitudes toward halophyte vegetable crops, i.e. *'agretti'*. Over 50% of Dr. Centofanti's time will be allocated for this project.

2. Dr. Hui Zhu

Contact information:

Dr. Hui Zhu
Department of Plant and Microbial Biology
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Description of qualifications:

Dr. Zhu is a visiting scholar as Wetland Ecologist at UC Berkeley. She has received a fellowship from the Chinese Academy of Science which completely finances her research residence in the U.S.A. She will be working in the laboratory of Prof. Terry for 2 years starting January 2015. Dr. Zhu is a senior research scientist at the Northeast Institute of Geography and Agro-ecology, Chinese Academy of Sciences, Changchun, China. She has been working on

wetland strategies and excessive nutrients and heavy metal removal for over 10 years. Dr. Zhu has supervised six large research projects, including two National Science Foundation programs in China. She has authored over 30 scientific publications, acknowledged with three science research awards, and supervised over 10 students. Her expertise include: monitoring wetland plants, roots and its rhizosphere, analyzing interactions between pollutants and the wetland system, and developing methods to enhance the purification ability of wetlands. Her wetland research skills certainly complement the pioneering wetland strategies developed earlier by Prof. Terry for Se removal.

Role as principal investigator:

Dr. Zhu brings her expertise into co-designing a mesocosm wetland system with 'agretti' for removal of excessive B and Se via rhizofiltration from saline drainage water. Her main responsibility will be to conduct the wetland mesocosm study under the supervision of Prof. Terry at UC Berkeley. She will be monitoring the wetland mesocosm and making drainage water solutions, sampling and analyzing plants, roots and water samples (see section 5). In addition, she will be writing sections of the quarterly, final and post-completion reports related to her tasks and she will be preparing scientific articles. She will present her work at local seminars and at UC Berkeley. Dr. Zhu will periodically visit the micro-plot study at Red Rock Ranch and will help with the analysis of soil plant profile (see task breakdown). Prof. Terry and Dr. Zhu will meet regularly with Dr. Centofanti and Dr. Bañuelos (see section 5 and 7) to discuss progress, issue and development of the wetland mesocosm study at UC Berkeley. See Appendix A for her CV.

Co-principal Investigator:

Dr. Florence Cassel

Contact information:

California State University Fresno

Center for Irrigation Technology

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Description of qualifications:

Dr. Cassel is assistant professor at CSU Fresno in the Department of Plant Sciences. She received a Ph.D. in Soil Science and Agronomy from the University of Wyoming. Dr. Cassel teaches undergraduate courses in soil and water management, irrigation systems, as well as agricultural laboratory techniques at the graduate level. Her research focuses on optimizing water use efficiency through low and deficit irrigation practices, improving irrigation scheduling, and utilizing remote sensing techniques for water resources management, crop water use, and soil salinity assessment with the EM 38 sensing technology. Dr. Cassel also serves as Assistant Director of Research of the Center for Irrigation Technology and has cooperatively worked under the supervision of Dr. Zoldoske for over 10 years. Dr. Cassel has 13+ years of experience in salt-affected and drainage impacted areas of the West side of the SJV. She has expertise in applying the remote sensing EM technology to evaluate and analyze spatial and temporal changes in soil salinity. Dr. Cassel has mentored and supervised over 100 undergraduate and graduate students. She has authored over 50 articles on soil and water management, including two books on the principles and applications of the EM technology for salinity assessment in the salt-affected soils of California. Approximately 15% of her time will be dedicated to this project. See Appendix A for her CV.

Role as Co-principal Investigator:

` Dr. Cassel will supervise all EM 38 remote sensing technology activities to be conducted at the field site at Red Rock Ranch. She will develop the protocol and design the complementary soil sampling to validate salinity parameters obtained by the EM 38 remote sensing technology. All data will be evaluated by her and validated with soil analysis performed at USDA-ARS research facilities. She will also co-supervise with Dr. Centofanti, the daily activities of the EM 38 technician from CSU Fresno (Mr. Thao) who will be hired part-time to help in the EM 38 remote sensing technology part of the project.

Dr. Cassel will analyze the data related to the EM 38 remote sensing technology, and she will write up sections of the quarterly reports, final report, and post-completion report related to her tasks.

Cooperators:

1. Prof. Norman Terry

Contact information:

Department of Plant and Microbial Biology

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Description of qualifications:

Prof. Terry is Professor of Environmental Plant Biology and researcher in the Agricultural Experiment Station at the University of California, Berkeley (UCB). He received his Ph.D. in Plant Physiology at the University of Nottingham, England, and joined the Berkeley faculty in 1972. At UCB he teaches advanced undergraduate courses on plant physiology, biochemistry, and environmental plant biology.

Prof. Terry is a world leader in the environmental remediation of heavy metal and metalloid pollutants in water and soils. He developed a research program that is a multi-disciplinary blend of environmental engineering, microbiology, plant biochemistry, and molecular biology. This approach is unique in phytoremediation research and has facilitated several innovative and creative solutions to environmental problems. Prof. Terry pioneered the use of constructed wetlands for cleanup of selenium and other toxic elements from oil refinery effluents and agricultural irrigation drainage waters. He has led four major constructed wetland projects for the cleanup of agricultural and industrial wastewaters: the Allegheny Power Service Constructed Wetland at Springdale, Pennsylvania; the Tennessee Valley Authority Constructed Wetland at Widows Creek, Alabama; the San Francisco Bay Constructed Wetland Treatment System at Richmond, California; and the Tulare Lake Drainage District Wetland at Corcoran, California. Prof. Terry pioneered the use of constructed wetland water treatment systems for the removal of Se from agricultural irrigation drainage water, research that continues to this day and has led to the current project. Using cutting edge molecular approaches, Terry developed transgenic plants with superior capacities for the phytoremediation of selenium and heavy metals (e.g., cadmium). And, by using sophisticated high energy x-ray absorption spectroscopy to

monitor elements speciation changes, he successfully demonstrated that plants have the ability to detoxify metals (e.g., chromium). During his research career Terry authored over 250 scientific articles. See Appendix A for his CV.

Role as cooperator:

Prof. Terry will supervise the wetland mesocosm system study to be conducted at UCB. Most importantly, he will provide detailed physiological analysis and insight on plant responses, i.e. mechanistic descriptions of salt compartmentalization strategies within 'agretti', which will explain the halophytic responses of 'agretti's ability to survive under these high saline conditions in wetland waters and in drainage irrigated soils at Red Rock Ranch. Prof. Terry will be responsible for supervising all research activities performed by Dr. Zhu and his team at UC Berkeley. Prof. Terry will also review the quarterly, final and post-completion reports, and scientific publications produced by Dr. Centofanti and Dr. Zhu.

2. Mr. Anand Murugesan

Contact information:

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Description of qualifications:

Mr. Murugesan is currently a lecturer in the Department of Economics, University of California, Merced. He is also completing a Ph.D. in Agricultural and Resource Economics at University of Maryland (Spring 2015). Mr. Murugesan obtained his M.S. degree in Applied Economics at University of Arizona and has worked on various research projects related to environmental, development and health issues such as indoor and outdoor air pollution, and local sanitation, water-borne diseases, and use of weather information for U.S. agriculture. Mr. Murugesan has cooperated and co-authored papers with Agricultural and Resource Economists both at UC Merced and University of Maryland. See Appendix A for his CV.

Role as cooperator:

Mr. Murugesan will provide insights and expertise in designing and implementing the survey to analyze consumers' preferences in relation to the newly produced 'agretti', and the potential for market development and consumers' demand for environmentally sustainable alternative produce. Mr. Murugesan will be responsible for developing the consumers' survey (from contacting the supermarkets' head office and arranging for permits to administering the survey) and delivering the survey. With the help of Dr. Centofanti, he will analyze the data and write up sections of the quarterly reports, final report, and post-completion report related to his tasks. He will also co-prepare with Dr. Centofanti scientific publication inherent to the study.

Other key personnel:

Baudelio Perez (CIT and USDA-ARS part-time field technician, see Appendix A for his CV), Justin King (CSU Fresno chemistry graduate student and part-time lab assistant at USDA-ARS, see Appendix A for his CV) will be available for all aspects of this project including field preparation, transplanting, micro-plot experiment development and execution, sampling, harvesting, samples processing and analyses. A part-time graduate student and EM 38 technician (Mr. Touyee Thao) from CSUF will be involved in all aspects of the EM 38 remote sensing technology (as described in section 6), including the implementation of experimental design, soil sampling and data processing.

2.1 Relationship amongst institutions cooperating in the project

As project manager, *Dr. Bañuelos* has long-term experience interacting with all cooperators; he has 18 years working relationship on drainage water related activities with *Mr. John Diener* owner of Red Rock Ranch, which provides a solid foundation for continuing their cooperation, especially in this proposed project. He and *John Diener* have initiated field pioneering work on developing biofuel and Se-enriched animal feed products from canola and mustard grown with selenium laden drainage waters on the West side of the San Joaquin Valley, as well as developed strategies for biofortifying other alternative crops, i.e. prickly pear cactus fruit, with selenium under salt stress growing conditions. The joint efforts have been well documented in three PBS television documentaries, as well as on news, radio and television programs, and national and international popular news magazines. As part of the effective

cooperation, *Dr. Zoldoske* and *Dr. Cassel* have worked with *John Diener* for over a decade developing water management strategies in saline soils, partly derived from extensive remote sensing EM salinity assessment surveys. In this regard, both *Dr. Zoldoske* and *Dr. Cassel* have worked over 10 years together on salinity-related issues for both soil and water in the West side of the SJV and in the Delta region of Central California. *Dr. Zolodoske*, *Dr. Cassel*, *Dr. Bañuelos*, and West side Resource Conservation District Board (led by Sarge Green) jointly worked together and co-produced a detailed salinity technical report titled: 'Landowners' Manual for Managing Agriculture Irrigation Drainage Water: A guide for developing Irrigated on-farm Drainage Management Systems for the State Water Resources Control Board' (2013). As additional evidence of cooperation amongst the project team members, *Dr. Bañuelos* has worked with *Professor Terry* on plant accumulation and volatilization of Se since the early 90s'. Much of their collaboration culminated in a well-known book titled: 'Phytoremediation of contaminated soil and water' (see publications by Bañuelos). Both *Professor Terry* and *Dr. Bañuelos* are nationally and internationally recognized for their research efforts related to salinity, plant responses, and the biological management of Se.

In the last two years *Dr. Centofanti* has worked with *Dr. Bañuelos* focusing on the biochemical interactions within plants as influenced by irrigation with poor quality water high in salinity, B and Se. This first-of-a-kind research provides nutritional insights into edible plants irrigated with saline water. In addition, *Dr. Centofanti'*s rich research experience with metal accumulation and plant eco-physiological responses to abiotic stresses is essential for determining the effect of drainage water re-use on the nutritional value of 'agretti' grown in both irrigated or wetland conditions. To complement and provide a realistic sustainability component to this proposal, agricultural and resource economist *Mr. Anand Murugesan* will provide economic analysis on the feasibility and potential acceptance of the newly produced 'agretti' in selected California markets (see section 3.3). *Dr. Centofanti* and *Mr. Murugesan* have a six year working relationship sharing common research interest on issues related to environment, agriculture and economic externalities produced by consumers' food choices.

2.2 Plan for project management

Dr. Bañuelos, as project manager, will be responsible for supervising all research activities performed by his team at USDA-ARS, and will coordinate all activities with all other

project cooperators and co-investigators: Dr. Centofanti, Dr. Cassel, Prof. Terry, Dr. Zhu, and Mr. Murugesan. Detailed task breakdown and project schedule are presented in section 5 and 7, respectively. In addition, to facilitate communication and data sharing amongst the members of the project team, regular meetings will be held at one of the research institutions in Fresno or Berkeley via video conference. Besides email, the use of technological devices and software (i.e. drop box, doodle, endnote, skype) will be implemented to facilitate data and literature sharing and maintain efficient communication. Dr. Centofanti and Dr. Zhu will be in continuous contact per email and phone on a weekly basis to discuss progress and/or issues and will report to their supervisors (Dr. Bañuelos and Prof. Terry, respectively) on a day-to-day basis.
The various project team members are involved in the development of the project according to their specific roles and tasks as outlines in section 2, 5, and 7.

2.3 Laboratories and facilities

In the USDA-ARS research facility at Parlier, CA, the Water Management Research Laboratory has over 1500 sq ft. available as chemical laboratories equipped with large outdoor plant and soil drying ovens, wood-chippers for plant grinding large plant samples, soil grinder, four fume hoods and facilities for acid and ash digestion (for digestion blocks, muffle furnace, microwave digester), Perkin Elmer inductively coupled plasma spectrometer (ICP) for all inorganic elements, Agilent ICP Mass Spectrophotometry for all minute concentrations of inorganic elements, especially Se, Thermo Jarrell Ash atomic absorption spectrometer for Se, Dionex ion chromatograph for anions, titrimeter for chlorides, Alpkem auto analyzer for nitrates and phosphates, Flash 2000 analyzer for total N and C, and conductivity/salinity meters for salinity measurements, environmental growth chambers, sterilized hood, and autoclaves. In addition a vacufuge® vacuum concentrator (Eppendorf, Westbury, NY), a Sorvall Evolution RC superspeed centrifuge (ThermoFisher Scientific, Waltham, MA), and Spectra Max plus 384 spectrophotometer (Molecular Devices, Sunnydale, CA) are available for the extraction and analysis of total phenolics and other antioxidants (i.e. flavonoids and anthocyanins). French press, electric juicer, blender, freeze drier, -20 C and -80 C freezers are available for sample processing and storage.

University of California Berkley

The wetland mesocosm system at UCB is currently operational and it has been used in the past for a number of projects (see publications by Terry). A description of the wetland mesocosm system is provided in section 6.

California State University, Fresno

Facilities at the Center for Irrigation Technology (CIT) at CSU Fresno to be used in the project comprise GPS instruments, ArcGIS software, and the Mobile Conductivity Assessment (MCA) System for EM sensing technology developed at California State University Fresno, as described in section 6.

Red Rock Ranch

Red Rock Ranch (RRR) is located near Five Points, CA, and will contain the large field site for the field-grown 'agretti'. All equipment, irrigation, field labor, and any equipment needed for conducting field operations, are available at RRR for field study. Dr. Bañuelos, Dr. Zoldoske, and Dr. Cassel have conducted a multitude of drainage water reuse studies over the last 15 years at RRR, where Dr. Bañuelos has concentrated his field efforts with drainage water on canola, mustard, prickly pear cactus, and poplar trees. John Diener will work in conjunction with Bañuelos staff on all field operations.

3. Scope of the Work and Project Description

In the west side of central California there is a shortage of good quality water available for irrigated agriculture due to severe drought, reductions in water allotments, and growing municipal, urban, and environmental demands. Hence, reuse of poor quality water in agriculture is one drainage water management option for the use of alternative water sources. The drainage reuse concept was implemented on field sites in the west side of the SJV by 'drainage water and drainage water reuse specialists'[1], who initiated and led many research activities from the 80's until recently. Some of their research emphasized that sustainable drainage water reuse requires particular attention toward crop selection, control of soil salination, and crop and soil management. In addition, the presence of natural-occurring Se and B salts in these soils and consequently in drainage waters produced in this part of California, must be managed to minimize their potential detrimental effects on soil quality and the biological environment. More detailed and insightful information on drainage water disposal is discussed by Ayars et al., (2013); Cevinka et al., (1999); Oster and Grattan (2002); Rhoads (1999); and Suyama et al., (2007).

One possible strategy to increase sustainability of management of the high levels of soluble Se and B is to identify drought and salt tolerant crops that can survive such growing conditions, and which possess ability to manage soluble B and Se via plant extraction and volatilization, respectively, in arid saline areas. Halophytic plant species possess a range of highly efficient and complementary morphological, physiological and anatomical characteristics to combat and even benefit from a saline environment (Flowers and Colmer 2008). While halophytes have long had a place in the diet of people around the world, scientific exploration of the potential for the use of halophyte as crop has only recently developed in the latter half of the 20th century (Panta et al. 2014). Although market development for saline agriculture has only just started, increased demand in the future is likely, because the sustainability of production of traditional crops is decreasing due to lack of good quality soil and water for their cultivation (Rozema and Schat 2013).

Introduction of selective halophytes in the saline soils of the western SJV could be an alternative strategy to foster resource efficient farming and support utilization of land or drainage

[1] Ayars J.E., Grattan S.R., Oster J.D. , Rhoades J.D., Kaffka S.R., Watson M.C., Suyama H., Benes S. E., and Cevinka V. (see References).

waters degraded by salinity B and Se. In this project, we will evaluate the salt removal ability of the halophyte *Salsola soda* L. to phyto-harvest specific ions, e.g., B, Se, Na, from both B and Se-laden soils irrigated with drainage water, as well as from drainage water circulating within a mesocosm wetland system. *Salsola soda*, more commonly known as 'agretti' (Fig. 1), is a halophyte native to the Mediterranean basin. It is a relatively small plant that grows to about 0.7 meters on average in soils located within coastal regions that are at times saturated with salt water. Hence, the plant may be a suitable candidate for a wetland system.

Throughout history, the plant was a very important source of soda ash, as people would extract the ashes from *S. soda*. The plant is no longer grown for the use of its soda ash but rather it is farmed as a vegetable. Various *Salsola* species are traditionally used in folk medicine for the treatment of hypertension, constipation and inflammation (Tundis et al., 2009). In this regard, alkaloid extracts from *Salsola* species have been evaluated for the treatment of Alzheimer's disease (Tundis et al. 2009).

Figure 1. Wild *S. Soda* growing on the coast near the sea water (left) and cultivated *S. soda* known as 'agretti' vegetable (right).

A preliminary study conducted by Centofanti and Bañuelos (2014) (see appendix B for copy of manuscript submitted to Journal of Environmental Management) in central California showed that *Salsola soda* can grow in saline (EC[2] >10 dS m^{-1}) and B-laden soils (10 mg L^{-1}) of the San Joaquin Valley, CA, and easily tolerate irrigation with saline and B rich water (EC 3 dS

[2] EC= Electrical conductivity

m^{-1} and 4 mg B L^{-1}). In this poor quality soil, under these growing conditions, the plant accumulated and removed high amounts of Na (80 g Na kg^{-1} DW), B (100 mg B kg^{-1} DW), and Se (3-4 mg Se kg^{-1} DW) without showing any toxicity symptoms (Fig. 2 and 3). Hence, *S. soda* showed promising potential as a plant species that can be irrigated and grown in saline and B-laden conditions and accumulate and harvest unwanted ions from the soil. We have no direct evidence of 'agretti's' ability to grow under wetland growing conditions, although the plant is commonly grown under salty marshy regions in coastal areas of the Mediterranean Europe. Apparently, the plant can survive under continuous wet and saline growing conditions.

Figure 2. *S. soda* (agretti) grown on saline soil (Oxalis silty clay loam) with EC >10 dS m^{-1}, water soluble B concentration of 10 mg L^{-1}, water soluble Se concentration of 0.2 mg L^{-1}, and water soluble Na concentration of 1470 mg L^{-1}. Plants were grown on the soil for 3 weeks; plants were 37 days old when the picture was taken.

Figure 3. *S. soda* (agretti) grown on non-saline soil (Hanford sandy loam) with EC <1 dS m^{-1}, water soluble B concentration of 0.12 mg L^{-1}, water soluble Se concentration of 0.002 mg L^{-1},

and water soluble Na concentration of 97 mg L^{-1}. Plants were grown on the soil for 3 weeks; plants were 37 days old when the picture was taken.

3.1 Project goals

The goal of the proposed study is to understand how 'agretti' can be grown and used on a sustained basis for phyto-harvest of Na, B and Se field soil drip-irrigated with drainage water, as well as in wetland conditions with simulated drainage water representative of the salinity, B, and Se levels as in the proposed field study at Red Rock Ranch (see section 6). There is absolutely no information on both growing *Salsola soda* with drainage water produced from the West side of the SJV, and on the use of this plant species in a wetland system with high salinity, B and Se drainage water. Understanding the impact that drainage water irrigation application strategies can exert on downward and lateral movement of salts and on sustaining 'agretti's' growth, as well as discovering 'agretti's' potential use in a wetland system, will help promote 'agretti' as an alternative crop for drainage water usage in the West side of the SJV. Estimating consumers' preferences and the potential market demand for alternative vegetable crops such as 'agretti', will be performed in cooperation with Mr. Murugesan at UC Merced. In this regard, a survey will be administered at various farmers' markets in Fresno and in the San Francisco Bay Area and in two representative supermarkets (e.g. Whole Foods and Savemart). To our knowledge, 'agretti' is currently grown in Watsonville, CA at the 'Mariquita Farm' (for more details visit: http://www.mariquita.com/), which sells its produce at the Ferry Plaza Farmer's Market, in San Francisco.

3.2. Project objectives

Our hypothesis is: 'Agretti' can be successfully and sustainably grown as a vegetable crop and to remove specific ions (phyto-harvest) from both saline soils surface drip irrigated with drainage water and from a wetland mesocosm system comprised of drainage water.

We propose to study the mechanisms of Na, Cl, B and Se uptake, translocation, and localization relative to halophytic characteristics of 'agretti' to maximize phyto-management strategy practices for this proposed alternative crop in two different but related studies under the following growing conditions: *experiment 1)* establish surface drip-irrigated micro-plots with

drainage water characterized by excessive salinity, B and Se soils[3] at Red Rock Ranch (Five Point, CA), and *experiment 2)* utilize mesocosm wetland system comprised of saline, B, and Se tainted waters conducted at UCB. The micro-plot experiment under drip irrigation will allow us to elucidate soil- root-shoot interactions that play a role in affecting salt movement in the soil, as well as evaluate water use efficiency and the performance of 'agretti' for phyto-management of Se, B, and Na, in saline soils (i.e., uptake and extraction efficiency of salts, B, and Se, and reduction of downward movement of soluble B, Se and salts). The 'mesocosm wetland system' (established under a controlled greenhouse environment) will allow us to study root-to-shoot relationships with Na, Se, B, and the plant's potential rhizofiltration capability within a wetland system. In addition, in cooperation with Mr. Murugesan at UC Merced, we will perform a study to estimate consumers' preferences and potential for market demand of 'agretti' grown in saline agriculture. The objective of the study is to assess consumers' preferences for alternative vegetable crop, such as 'agretti', grown in the West side of the SJV under environmental sustainable practices.

All these components and objectives of the project will be funded by DWR. The project does not constitute a phase of a larger, multi-phase project.

Specifically, in *experiment 1*, we intend to evaluate 'agretti's' salt (Na and Cl) and B tolerance and accumulation of Se, B, and Na from the harvested shoots and repeated cuttings thereof when grown in micro-plots at RRR. Irrigation drip strategies supervised by Dr. Zoldoske (CSU Fresno), i.e. varying irrigation application rates based upon ET°, will be further developed specifically for promoting sustainability of the saline micro-plot, via irrigation management of salt and B movement within the soil profile of the rooting zone. Dr. Cassel (CSU Fresno) will utilize EM 38 (electromagnetic induction, see section 6 for explanation) device for mapping and monitoring of water and salts lateral and vertical movement throughout the irrigated soil profile, as a result of manipulating irrigation delivery.

The following questions/objectives will be analyzed in *experiment 1*:

[3] Soil salinity in the micro-plot soil ranges from 10 to 21 dS m^{-1}, soluble B from 8-18 mg L^{-1}, and soluble Se 0.175-0.500 mg L^{-1}. Our proposed micro-plots (total area of 0.5 ha) have been irrigated for a multiple years with saline drainage waters.

1. Can ‘agretti’ tolerate and thrive under the salinity and B levels in the field at Red Rock Ranch?
2. Can the plant’s root system and ion uptake by ‘agretti’ reduce the downward movement of soluble B, Na, Cl, and Se?
3. How is the downward and lateral movement of soluble B, Na, Cl and Se (as observed by the EM 38 remote sensing technology) affected by the irrigation drip delivery strategies developed for saline and B-laden soils?
4. What is the water productivity of ‘agretti’ relative to the various irrigation rates used in the experiment? Do reduced irrigation rates (deficit irrigation) affect yield?
5. Where are Na, B and Se localized within the plant?
6. What are the Na, B, and Se extraction efficiencies of ‘agretti’?
7. What is the antioxidant content of ‘agretti’ and does irrigation with drainage water increase antioxidants content in plant’s shoots? (This question will be answered during the second year of the proposed project)
8. In which chemical forms is Se stored in the shoots?
9. Is Se volatilization also occurring?
10. What are the Na, Cl, B, and Se uptake levels in plant shoots after repeated cuttings of ‘agretti’?

In *experiment 2*, we will evaluate the eco-physiology and Na, B, and Se accumulation by ‘agretti’ in a ‘mesocosm wetland system’ at UCB (developed by Prof. Terry).

The purpose of the present work is to use wetland mesocosm to evaluate a constructed wetland water treatment system planted with ‘agretti’ to not only remove Se but also Na and B from simulated drainage water. The use of the mesocosm wetland system in a controlled greenhouse environment will allow us to evaluate the rhizofiltration potential of ‘agretti’ using drainage water that possess similar chemical characteristics (e.g. salinity, B and Se concentrations) of drainage water applied to the micro-plot at Red Rock Ranch.

In this experiment, we aim to discern mechanisms of B tolerance in ‘agretti’ and quantify the plant’s potential for rhizofiltration and phyto-management of Na, B and Se contained in drainage water.

The following questions/objectives will be analyzed in *experiment 2*:

1. What are the plant's responses to a mesocosm wetland system operating on water high in salinity, B, and Se?
2. What are the physiological mechanisms of B tolerance in agretti? (This question will be answered during the second year of the proposed project)
3. What are the B levels that 'agretti' can tolerate in wetlands? (This question will be answered during the second year of the proposed project)
4. Where is Na, B and Se localized within the plant's parts?
5. In which chemical forms is Se stored in the shoots?
6. Is Se volatilization also occurring?
7. Is 'agretti' a potential plant for rhizofiltration of saline water rich in Na, B and Se?

In the phytomanagement of poor quality water laden with B, Se, and salts, projected field scale constructed wetland approaches should have the lowest construction and operation costs for specific ions removal. Earlier research from Prof. Terry's laboratory (UC Berkeley) has shown that constructed wetlands planted with other plant species, i.e. cattail, were able to remove up to ~ 90% of the inflow Se from oil refinery wastewater, and have also been shown to remove significant amounts of Se from waters contaminated with agricultural irrigation drainage water.

In the study on evaluating consumers' preferences and potential market demand for 'agretti' produced from saline drainage waters we will address the following questions/objectives:

1. What is the consumers' knowledge/awareness of produce from saline agriculture, i.e., halophytes and salt-tolerant plants?
2. Would consumers be willing to buy 'agretti' (we will show fresh harvested 'agretti' to the consumers during our survey)? We will estimate consumers' willingness to pay (WTP) for `agretti' produced from saline agriculture.
3. What triggers consumers' demand towards alternative crops such as 'agretti'?
4. Does showing information on nutritional value of the product, culinary and cooking aids on how to prepare and consume the vegetable and sharing information on the agricultural sustainable practices used to grow the product and consequent impact on drainage water usage stimulate consumers' demand? By how much?

5. What are the sales and marketing strategies adopted by supermarkets (we will select: Whole Foods and Savemart) to introduce new and environmentally friendly produce to consumers?
6. What is the response of those supermarkets' customers to our survey? Is there a match in sales and marketing strategies of the supermarket with their consumers' behavior in terms of food choices/preferences? In other words, are the supermarket's sales strategies influencing consumers' choices?

3.3 Description of the location where the project will take place

1. Micro-plot study is located at Red Rock Ranch, Five Points, CA. A map of the field and other information are provided below in Figure 4. The micro-plots are located at: 36'22'51.45'N and 120'13'49.28'W.

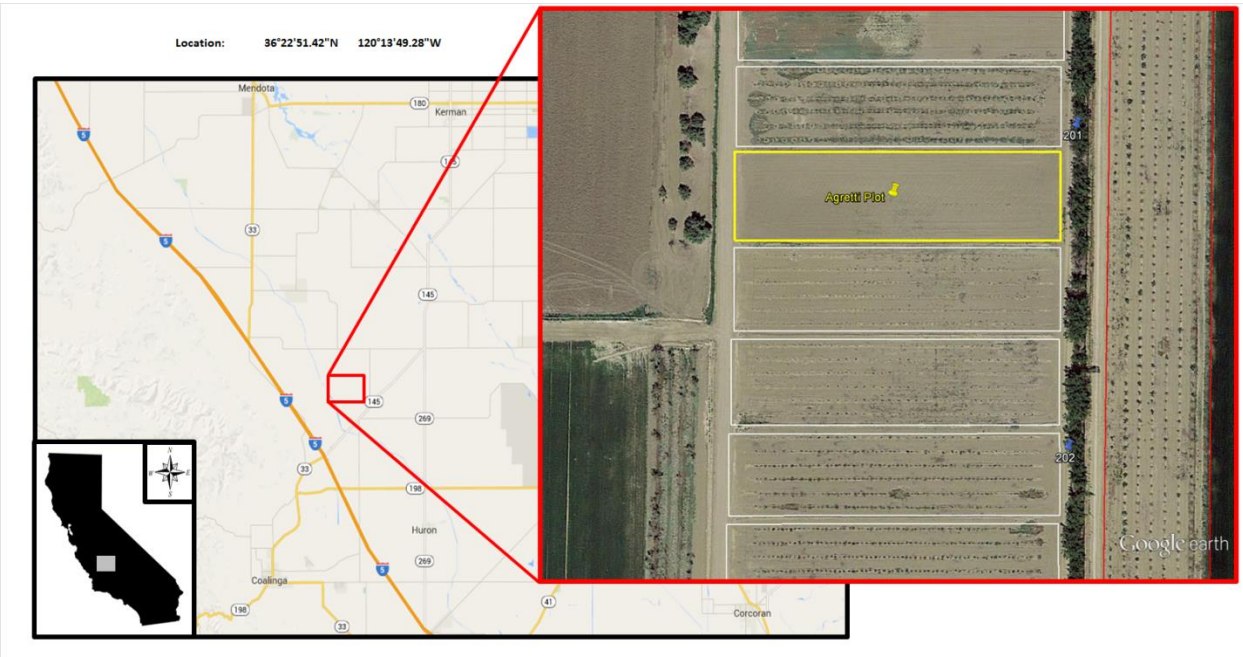


Figure 4. Map and location of the field site for the proposed micro-plot study, the area highlighted in yellow represents the location of the micro-plot.

2. Wetland mesocosm system is located at UC Berkeley in the laboratory and greenhouses of Prof. Terry (for more information visit: http://nature.berkeley.edu/terrylab)

3. We plan to administer the economic study (survey) in the following locations:

- Vineyard Farmer's Market in Fresno (located on the Northwest Corner of Blackstone & Shaw, for more information visit: http://www.vineyardfarmersmarket.com)
- Rue and Gwen Gibson Farmer Market (located at 5638 N. Chestnut Ave, for more information visit: http://www.fresnostate.edu/agf/farmmarket)
- Ferry Plaza Farmer's Market in San Francisco, at the Ferry Building in downtown San Francisco, at the base of Market Street on the Embarcadero
- Santa Cruz Farmer's market at Cedar St & Lincoln St, Downtown Santa Cruz
- One Whole Foods supermarket in San Francisco, Santa Cruz and Fresno, exact location the supermarket is to be defined with the Whole Food's area manager
- One Savemart supermarket in San Francisco, Santa Cruz and Fresno, exact location the supermarket is to be defined with the Savemart's area manager

3.4 Overview of outcomes and deliverables

1. Micro-plot drip-irrigation study

In this experiment we expect to obtain data on:

a) Movement of ions (i.e., Na, Cl, B, and Se) within the soil profile, both by chemical characterization in soil samples (ions concentration as a function of irrigation strategy, soil depth, and root presence) and by imaging and mapping using the EM 38 remote sensing technology
b) Plant tolerance related to toxicity/deficiency symptoms
c) Plant's water use efficiency calculated based on the amount of water used and biomass production within a set time frame
d) Plant shoot biomass production per cutting and uptake and translocation of Na, Cl, B and Se in the shoots
e) Concentration of total macro- (Ca, K, Mg, P, S) and micro-nutrients (Cu, Fe, Mn, Mo, Ni, Zn) and other elements (As, Cd, Co, Cr, Pb) in shoots and roots
f) Concentration of total and available (water extractable) macro- (Ca, K, Mg, P, S) and micro-nutrients (Cu, Fe, Mn, Mo, Ni, Zn) and other elements (As, Cd, Co, Cr, Pb) in soil
g) Concentration of antioxidants (i.e., phenolics compounds) in shoots
h) Root development analysis along the soil profile and concentration of Na, Cl, B, and Se in the roots sampled after analysis of soil profile and by auger sampling

i) Chemical speciation of Se within the plant shoots and roots
j) Volatilization of Se during the entire growing cycle in the surface drip-irrigated micro-plot at Red Rock Ranch

2. Wetland mesocosm system

In this experiment we expect to obtain data on:

a) Performance of 'agretti' in a mesocosm wetland system related to plant growth, toxicity and/or deficiency symptoms
b) Physiological mechanisms of B tolerance in 'agretti' by analyzing the concentration of B in the various plant parts such as stem, leaves, and roots, as well as the B concentration in the wetland waters at harvest and time 0 (before planting)
c) Plant shoot and root biomass production per cutting and concentration of Na, Cl, B and Se in shoots and roots
d) Concentration of total macro- (Ca, K, Mg, P, S) and micro-nutrients (Cu, Fe, Mn, Mo, Ni, Zn) and other elements (As, Cd, Co, Cr, Pb) in shoots and roots
e) Concentration of antioxidants (i.e., phenolic compounds) in shoots
f) Chemical speciation of Se within the plants shoots and roots
g) Volatilization of Se during the entire growing cycle in the wetland mesocosm
h) Concentrations (at time 0 before planting, and at each cutting) of total macro- (Ca, K, Mg, P, S) and micro-nutrients (Cu, Fe, Mn, Mo, Zn) in water, including Na, Cl, B and Se in drainage water over time

3. Assessment of market demand for 'agretti'

In this experiment we expect to obtain data on:

a) Consumers' knowledge/awareness of produce from saline agriculture, i.e. halophytes and salt-tolerant plants
b) Consumers' willingness to pay (WTP) for food products produced from saline drainage water
c) Potential triggers to increase consumers' preference towards alternative crops
d) Sale and marketing strategies adopted by Supermarkets (the case of Whole Foods and Savemart) to introduce new and environmentally friendly produce to consumers
e) Response of those supermarkets' clients to our survey in relation to their preferences for environmentally friendly produce

Obtaining all the data (as described above) within the proposed scheduled time frame (see section 7) will assure timely submissions of the mandatory grant reporting tasks. For each component of the project, as described above, the following deliverables are expected:

a) Invoices
b) Quarterly reports
c) Final reports
d) Post-completion report
e) Scientific publications

During the micro-plot drip-irrigation field study, demonstration days will be organized by project team members (USDA-ARS and CSUF) at Red Rock Ranch during the second year of the proposed project to demonstrate performance and adaptability of 'agretti' to drainage water reuse on poor quality soils typical of the west side of the SJV. Local growers, state and federal agencies, research scientists, and mass-media will have the opportunity to attend the field day, including culinary and consumer uses demonstrations. Local growers, food packers (e.g., Wawona), Whole Foods and Trader Joes Markets, Java Juice Company, state and federal agencies, research scientists, personnel from Great Valley Center, Modesto, CA, and mass-media will have the opportunity to view the newly-grown 'agretti' as well as another alternative crop, Opuntia (prickly pear cactus fruit), financially supported earlier by proposition 204 support.

4. Project Objectives and Program Priorities

The project's objectives are as follows (see section 3.2 for more details):

1. Investigate and develop the halophyte 'agretti' as alternative crop in poor quality soil with drainage water typical of the West side of the SJV and in mesocosm wetland system operated with poor quality drainage water
2. Evaluate 'agretti's' ability to tolerate drainage water applied via irrigation, as well as in a wetland and estimate the amount of phyto-harvested Na, Cl, B, and Se in its shoots after repeated cuttings
3. Quantify plant's water use efficiency
4. Quantify the downward and lateral movement of soluble Na, Cl, B, and Se with the EM 38 remote sensing technology as affected by drainage water application rates

5. Quantify the chemical forms of Se in ‘agretti’
6. Evaluate the antioxidant content of ‘agretti’ and determine whether drainage water applied via drip-irrigation and in a mesocosm wetland system increases the antioxidant content in ‘agretti’
7. Quantify selenium volatilization from drip-irrigated soil and from drainage water in wetland mesocosm system
8. Evaluate potential of ‘agretti’ for rhizofiltration of drainage water by phyto-harvesting Na, Cl, B, and Se
9. Evaluate the potential for market development and consumers’ demand for produce grown in saline agriculture, i.e. ‘agretti’

This project aims at developing sustainable and environmentally acceptable methods to concentrate and phyto-harvest Na, Cl, B, and Se from drainage water by using salt-tolerant plants, i.e., ‘agretti’ (both in field soil and wetland system). Hence, this project meets program priority #1 as stated in section D page 4 of the Drainage Reuse Grant Program Guidelines and PSP.

In addition, this project addresses and fulfills three of the stated knowledge gaps:

1. Management practices for irrigation, control of drainage water, and selection and management of salt-tolerant and halophytic plant cultures to ensure long-term sustainability of soil/water/plant systems.

The halophytic ‘agretti’ has been identified by Centofanti and Bañuelos (2014) (see Appendix B for copy of manuscript) as a salt and boron tolerant plant that can be used to harvest the soluble salts of Na, B, and Se from saline soils, while being irrigated with saline water under greenhouse conditions. The proposed micro-plot and mesocosm wetland system will be the first to demonstrate the plant’s ability to harvest the salts, i.e. specific ions, under field and wetland conditions. Importantly, we will determine the best rates of drainage water irrigation delivery (based upon ET° losses) for sustaining plant growth, while growing in saline soils and receiving drainage water produced at Red Rock Ranch. Our two-year experiment should provide us with practical and useful agronomic information for successfully producing an alternative and viable crop that has economic value, as well as a crop that can extract specific salt ions from drainage water application, as well as from drainage water circulating in a mesocosm wetland system.

2. Impacts of continuous irrigation with high salinity drainage water on leaching requirements, evapotranspiration, soil permeability, infiltration rates, soil compaction, soil salinity, and other chemical and physical properties of soil/water/plant system.

Information collected from the EM 38 remote sensing technology in conjunction with the complete macro- and micro-nutrient profile, including Se, B, Na, and Cl, will clearly provide us essential knowledge on the uptake and lateral and vertical movement of salts (i.e. ions) as influenced by rates of drainage water on vegetated and bare plots. This detailed analysis will provide practical information on managing salt movement via rates of irrigation application, as well as determine the impact of irrigation rate on enhancing or decreasing the plant's ability to accumulate and harvest salts (ions), including Se, from soil drip irrigated with drainage water. In addition, we will learn the most effective irrigation rate of drainage water to sustain the plant's growth and for preserving the physical quality of soil irrigated with drainage water on a continued basis. Saturation percentage (SAR) estimation at different depths will provide us with needed information on the efficacy of both irrigation delivery and plant uptake of Na on minimizing sodium's adverse effects on water infiltration and soil compaction.

3. Market opportunities for salt-tolerant plants, halophytic plants, and trace element accumulating crops.

We will evaluate consumers' preferences and market demand for 'agretti' as an alternative vegetable product grown under unique growing conditions, i.e. irrigated with water containing salinity and selenium. In addition, consumers' preferences will be evaluated with regard to 'agretti's' nutritional characteristics (e.g., antioxidant content) and 'agretti's' ability to take up Se and result in a Se-enriched product. This study is one of the first to evaluate market opportunity for halophyte produced in the SJV.

5. Task Breakdown

5.1 Experiment 1: Field micro-plot study

Experiment 1: field micro-plot study						
Task description	**Current status**	**Proposed costs**	**Schedule**	**Performance measures**	**Expected outcomes**	**Deliverables**
Field preparation: a) soil ploughing b) herbicide application c) installation of drip irrigation system	No activity	Field technician's time for ploughing and installation of irrigation system $599 (>36 hr at $15/hr +11% benefit); $1,750/year x 2 years =$3,500 for herbicide purchase and application, and for purchase of tubing, other miscellaneous irrigation supplies	July 1-10, 2015 May 2-13, 2016	Assure that irrigation system is working and soil is clear of weeds at that time	Field sites are ready for transplants by July 13 and the irrigation system is operational	Invoices
'Agretti' seed germination	No activity	$280 to buy seeds ($10 per pack, total of about 28 packs), a box contains approximately 2,000 seeds. Minimum germination is 65%. Seed germination will be performed at Red Rock Ranch at the cost of $500 x 2 years =$1,000	July 1-15, 2015 May 2-16, 2016	Seeds are germinated in a commercial greenhouse and seedlings will be ready for transplant when the experiment is scheduled to commence	Receive healthy seedlings to be transplanted in the field	Invoices
Transplant of seedling to field sites	No activity	Field technician's time: $1,665 (100 hours at $15/hr + 11 % benefit) and student's time: $810 (50 hours at $15/hr for two workers + 8% benefit); travel costs for trips to and from Red Rock Ranch - Parlier ($56 per return trip, 12 trips = $672 for 2 years)	July 16-17, 2015 May 17-23, 2016	Seedlings survive the transplant and are successfully growing in the field soil	Seedlings begin to grow and thrive in the field soil	Invoices

Experiment 1: field micro-plot study						
Task description	**Current status**	**Proposed costs**	**Schedule**	**Performance measures**	**Expected outcomes**	**Deliverables**
Development and execution of field experiments: a) monitor plant growth b) maintain operation of drip irrigation system c) control weeds, gophers and rabbits d) field demonstration	No activity	Dr. Centofanti's time: $22,200 (>500 hr. at $40/hr. +11% benefit); field technician's time: $6,660 (400 hours at 15$/hr. + 11 % benefit,) and student's time: $3,240 (200 hours at 15$/hr. + 8% benefit), travel costs for trips to and from Red Rock Ranch - Parlier (56$ per return trip x 20 trips/year x 2 years= $2,240)	July 20 to November 20, 2015 May 24 to September 26, 2016	The field experiment is successful when plants thrive in the field and no major external factors (e.g., rabbit, gophers or rodents attack) influence plant performance	Expected outcomes are described in detail in section 3.4. The major outcome expected for these tasks is to obtain plant and soil data and results	See section 3.4. Invoices
EM 38 remote sensing technology	The Mobile Conductivity Assessment (MCA) System is available for scientific project at Fresno State	Dr. Cassel's time: $26,640 (600 hr. at $40/hr. +11% benefit); EM 38 remote sensing technician's time: $21,645 (1,300 hours at 15$/hr. + 11 % benefit,); ooperational costs for the Mobile Conductivity Assessment (MCA) System (see section 6) $2,500/year x 2 years= $5,000 Travel costs for trips to and from Red Rock Ranch - Parlier (58$ per return trip x 20 trips/year x 2 years = $2,330)	July 31 to November 10, 2015 June 1 to September 12, 2016	The MCA system is functional and operates well on the field site	Expected outcomes are described in detail in section 3.4. The major outcome expected for these tasks is to obtain soil data and results	See section 3.4. Invoices

Experiment 1: field micro-plot study						
Task description	**Current status**	**Proposed costs**	**Schedule**	**Performance measures**	**Expected outcomes**	**Deliverables**
Collection of soil and plant samples and samples processing	No activity	Dr. Centofanti's time: $22,200 (>500 hr. at $40/hr. +11% benefit); field technician's time: $8,325 (500 hours at $15/hr. + 11 % benefit) and students' time: $4,050 (250 hours at $15/hr. for two workers + 8% benefit); purchase of lab supplies (zip log bags, plastic containers, etc.) $1,000 x 2 years = $2,000	August 3, 2015–March 21, 2016; May 24, 2016 to February 24 , 2017	Samples are collected and processed carefully and efficiently	Expected outcomes are described in detail in section 3.4. The major outcome expected for these tasks is to obtain plant and soil data and results	See section 3.4. Invoices
Analysis of soil profile	No activity	Dr. Centofanti's time: $11,100 (>250 hr. at $40/hr. +11% benefit); field technician's time: $4,163 (250 hours at $15/hr. + 11 % benefit,)and students' time: $2,106 (130 hours at $15/hr. for two workers + 8% benefit); purchase of lab supplies (plastic sheets, tarps, plastic containers, etc.) $500 x 2 years =$1,000	August 3 to November 20, 2015; May 30 to September 12, 2016	Samples are collected and processed carefully and efficiently	Expected outcomes are described in detail in section 3.4. Obtain soil data is the major outcome expected for this task	See section 3.4. Invoices
Samples analysis	State of the art instruments and equipment are currently available at USDA in Parlier	Dr. Centofanti's time: $8,880 (>200 hr. at $40/hr. +11% benefit); argon gas to operate instruments (see section 6 for details on methods) 1 tank of argon at $400 runs 500 samples; hence eight tanks of argon are needed, $3,200; lab supplies (pipette tips, tubes, reagents, flasks, vials, etc.) $5,000 x 2 years = $10,000	November 18, 2015 to march 23, 2016; September 27, 2016 to February 24, 2017	Samples are analyzed promptly and data are obtained for the preparation of the reports	Expected outcomes are described in detail in section 3.4. Obtain soil and plant data is the major outcome expected for this task	See section 3.4. Invoices

Experiment 1: field micro-plot study						
Task description	**Current status**	**Proposed costs**	**Schedule**	**Performance measures**	**Expected outcomes**	**Deliverables**
Data analysis and preparation of quarterly reports and publications	No activity	Dr. Centofanti's time: $21,312 (>480 hr. at $40/hr. +11% benefit)	August 3, 2015 to May 31, 2016: October 10, 2016 to May 31, 2017: September 1 -30, 2015; December 1-31, 2015; March 1-31, 2016; June 1-30, 2016; September 1-30, 2016; December 1-31, 2016; March 1-31, 2017; June 1-30, 2017	Reports are completed within the time frame assigned	Quarterly reports	Quarterly reports
Preparation of final report	No activity	Dr. Centofanti's time: $3,552 (>80 hr. at $40/hr. +11% benefit)	July 3-31, 2017	Report is completed within the time frame assigned	Final report	Final report
Preparation of post-completion reports	No activity	Dr. Centofanti's time: $3,552 (>80 hr. at 40/hr. +11% benefit) $	August 1-31, 2017	Report is completed within the time frame assigned	Post-completion report	Post-completion report

5.2 Experiment 2: Wetland mesocosm system

Experiment 2: wetland mesocosm system						
Task description	**Current status**	**Proposed costs**	**Schedule**	**Performance measures**	**Expected outcomes**	**Deliverables**
'Agretti' seed germination	No activity	$140 to buy seeds (10$ per pack, total of about 14 packs), a box contains approximately 2,000 seeds. Minimum germination is 65%. Seed germination will be performed in greenhouse at UC Berkeley	July 1-15, 2015 May 2-16, 2016	Seeds are germinated in the greenhouse and seedlings will be ready for transplant when the experiment is scheduled to commence	Obtainment of healthy seedlings to be transplanted in the wetland mesocosm system	Invoices
Preparation of wetland mesocosm and execution of experiments	Facilities and equipment are available at UCB	Greenhouse supplies (shade cloths, lamp bulbs, fans, etc) and mesocosm system supplies (plastic tanks and lids, tubing, etc.) $4,000 x 2 years = $8,000	July 17 to November 17, 2015 May 17 to September 19, 2016	The experiment is successful when the plants are healthy and grow well in mesocosm wetland system	Expected outcomes are described in detail in section 3.4.Obtainment of data is the outcome expected for this task	Invoices
Collection of water and plant samples and samples processing	No activity	Lab supplies (reagents, tubes, flasks, and vials for samples storage and analysis) $3,000 x 2 years = $6,000	August 3 to March 23, 2016 May 18, 2016 to February 20, 2017	Samples are collected and processed carefully and efficiently	Expected outcomes are described in detail in section 3.4.	See section 3.4. Invoices

Experiment 2: wetland mesocosm system						
Task description	**Current status**	**Proposed costs**	**Schedule**	**Performance measures**	**Expected outcomes**	**Deliverables**
Samples analysis	State of the art instruments and equipment are available at UCB	Argon gas to operate instruments (see section 6 for details on methods), 1 tank of argon at $400 runs 500 samples: hence six tanks of argon are needed, $2,400	November 18, 2015 to March 23, 2016; August 1 to December 30, 2016	Samples are analyzed promptly and data are obtained for the preparation of the reports	Expected outcomes are described in detail in section 3.4. Obtain plant data is the major outcome expected for this task	See section 3.4. Invoices
Data analysis and preparation of quarterly reports and publications	No activity		September 1 -30, 2015; December 1-31, 2015; March 1-31, 2016; June 1-30, 2016; September 1-30, 2016; December 1-31, 2016; March 1-31, 2017; June 1-30, 2017	Reports are completed within the time frame assigned	Quarterly reports	Quarterly reports

5.3 Experiment 3: Economic analysis

Experiment 3: economic analysis						
Task description	**Current status**	**Proposed costs**	**Schedule**	**Performance measures**	**Expected outcomes**	**Deliverables**
Establish of contact with supermarkets and farmers' markets to obtain permits to carry out the survey and questionnaire to consumers	No activity	Mr. Murugesan's time: $1,776 (40 hr. at $40/hr. +11% benefit)	July 1-31, 2015 May 2-June 21, 2016	Obtain clearance to administer the survey questionnaire to consumers	Obtain clearance to administer the survey questionnaire to consumers	Invoices
Preparation and delivery of questionnaire	No activity	Mr. Murugesan's time: $2,664 (60 hr. at $40/hr.+11% benefit)	July 1-31, 2015 June 1-30, 2016	Sample and survey design for individual consumers questionnaire	Sample and survey design for individual consumers questionnaire	Invoices
Delivery and execution of survey to consumers	No activity	Travel costs to and from the locations chosen (San Francisco and Santa Cruz) $1,500; stationary and computer supplies $500	August 3-31 2015; July 1-29, 2016	Administer the survey, analysis and delivery of preliminary summary report	Expected outcomes are described in detail in section 3.4.	Invoices
Data analysis and preparation of quarterly reports and publications	No activity	Mr. Murugesan 's time: about $3,552 (>80 hr. at $40/hr. +11% benefit)	August 3, 2015 – May 31, 2015; October 3, 2016 – May 31, 2017; September 1 -30, 2015; December 1-31, 2015; March 1-31, 2016; June 1-30, 2016; September 1-30, 2016; December 1-31, 2016; March 1-31, 2017; June 1-30, 2017	Reports are completed within the time frame assigned	Quarterly reports	Quarterly reports

5.4 Meetings, field demonstration, and project administration

Meetings, seminars, field demonstration, and project administration						
Task description	**Current status**	**Proposed costs**	**Schedule**	**Performance measures**	**Expected outcomes**	**Deliverables**
Visits between Parlier, Fresno, and Berkeley	Cooperation is ongoing among all investigators involved in the project (see section 2) and the individuals have been in continuous contact for the preparation of the project proposal	Travel costs, including food and accommodation for at least 8 visits ($500/visit x 8 visits = $4,000)	June 23-26, 2015; August 3-7, 2015; August 24-26, 2015; November 16, 2015; May 9-13, 2016, June 13-17, 2916, July 6-8, 2016, November 14, 2016	Cooperation between investigators continues to be productive and inspiring for all the persons involved in the project	Successful project development and timely and accurate delivery of outcomes and deliverables	Quarterly reports, final report, and post-completion report
Field demonstration	Dr. Bañuelos has a long-term experience with field demonstrations at Red Rock Ranch	In-kind and federal funds (section 8.1.3)	June 13-17, 2016	Successful and productive field day with high attendance of farmers and potential consumers	Positive reception of 'agretti' by farmers in the West side of the SJV and adoption of growing the vegetable	Inclusion of field demonstration day in the quarterly report
Project administration	No activity	Preparation of pay slips and invoices Mrs. Suryadi's time: $7,992 (240 hr. at $30/hr.+11% benefit) Dr. Zolodske's time: $3,641(40 hr. at $82/hr. +11% benefit)	July 1, 2015 to June 1 2017	Administration of the project is efficient and functional	Payment of salaries and invoices execution	Timely submission of all invoices

6. Materials, Methods, and Scientific Merit

6.1 Experiment 1

6.1.1 Micro-plot field site

The saline, B and Se-laden micro-plot chosen for the study is located at Diener's Red Rock Ranch (RRR), Five Points, CA (see Fig. 4). The soil is classified as an Oxalis silty clay loam (fine montmorillonitic, thermic Pachic Haploxeral with a well-developed salinity profile). Soil salinity in the micro-plot soil ranges from 10 to 21 dS m^{-1}, soluble B from 8-18 mg L^{-1}, and Se from 0.175-0.500 mg L^{-1}. There are two micro-plots available, each with 18 beds, respectively. A schematic representation of the field micro-plots is shown in Figure 5. Within each micro-plot, 9 beds (30 x 1.6 m, individually) will be planted to 'agretti' (vegetated) and 9 beds will be bare (not vegetated). A surface-drip irrigation system will be installed consisting of one in-line turbulent flow emitter per bed with an emitter spacing of 0.45 m and a flow rate of 4 L/h. Using this surface drip irrigation delivery system, drainage water treatments for vegetated and bare plots will be based upon applying water at rates of 100%, 75%, and 50% of ET° in both micro-plots. These treatment rates of water application will be completely randomized and each treatment will be replicated 6 times on both vegetated and bare plots. Drainage water composition at this site will generally have salinity levels ranging from 4-8 dS m^{-1}, 4-8 mg B L^{-1} and 0.12-0.25 mg Se L^{-1}. See Figure 6 for origin of drainage water.

'Agretti' will first be germinated in trays and grown for one month in the greenhouse before transplanting into the field. In the planted plots (vegetated), plants will be spaced 10-20 cm apart in two rows and will be 50 cm apart from each other, while the unplanted plots will be un-vegetated. Good quality water may be used at time of transplanting to promote initial establishment of plants. The plants will be grown in the field for a total of 4 months. The different irrigation rates are used to determine the best rate of applying drainage water to better manage salt movement within the soil profile, promote water use efficiency of 'agretti' and increase plant biomass production and the ability of the plant to phyto-harvest salty ions.

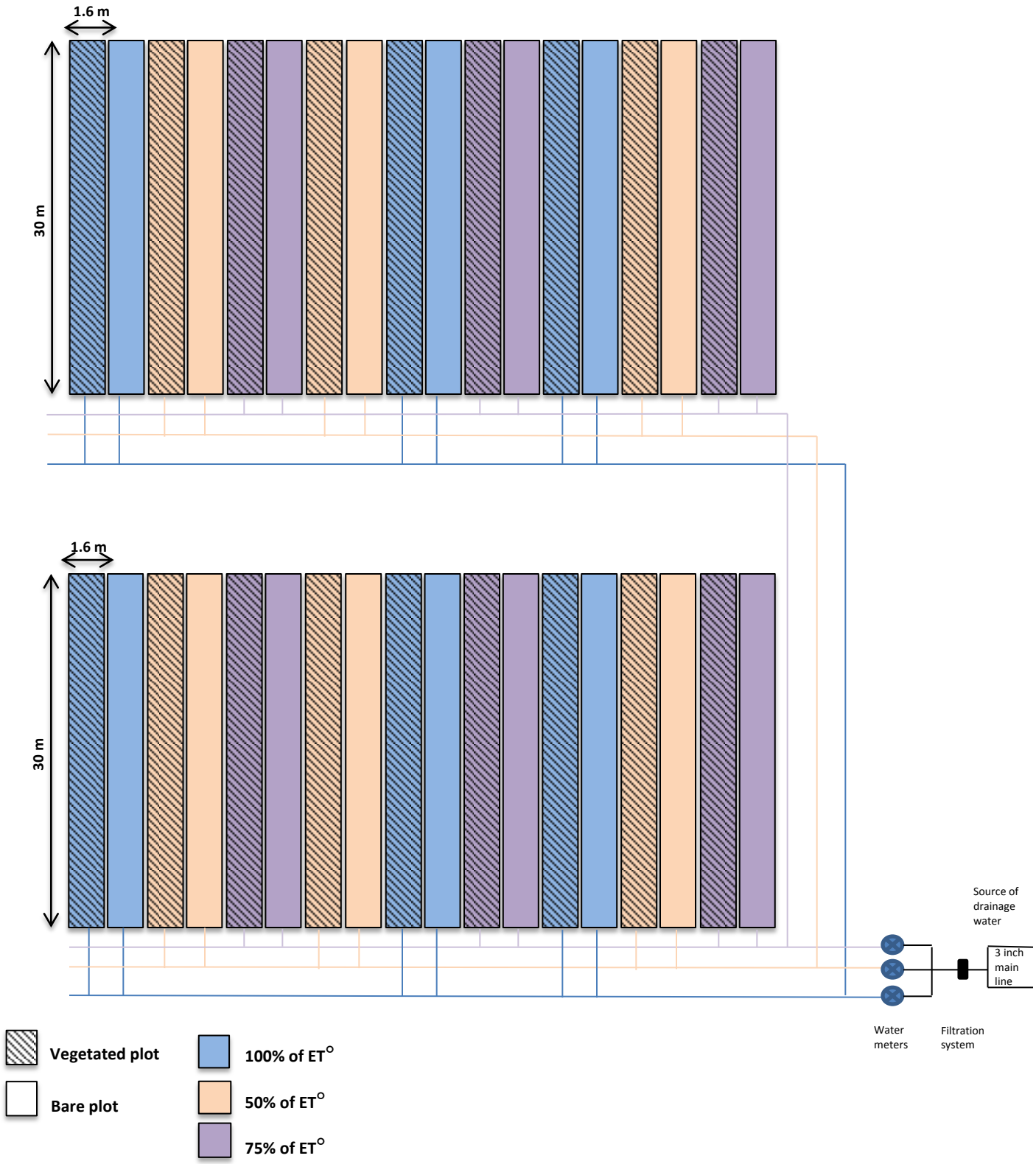


Figure 5. Micro-plots layout with location of the planted and unplanted areas and irrigation system at Red Rock Ranch, Five Points, CA.

Figure 6. The 'Agretti' field plot will be irrigated with drainage waters collected from either field A, B, C and D (showing field B as the closest field to drainage pond) during the growing season. The drainage water will consist of surface collected drainage from furrow irrigation and center pivot irrigation. Additional water will be collected from the subsurface tile drainage system. Both waters will be collected and available in the drainage pond. The drainage water will then be pumped, filtered and utilized in the 'agretti' field plot surface drip irrigation system.

6.1.2. Monitoring and assessment of soil salinity using EM 38 remote sensing technology based on drainage water quality

Monitoring the movement of salts and specific ions in vegetative and bare plots as influenced by drainage water irrigation application rate, is key to understanding water management strategies to advance sustainability of food production in central California.

Soil salinity changes with drainage water reuse and it is difficult to quantify because of rapid changes over space and time in soil profile. The electromagnetic (EM) induction technique has become a very useful and cost-effective tool to monitor and diagnose soil salinity over large areas, because it allows for rapid and above-ground non-invasive measurements (Cassel and Zoldoske 2006). Additionally, EM sensors generally provide better and faster estimates of soil salinity than direct methods.

The Mobile Conductivity Assessment (MCA) System developed at California State University Fresno is comprised of four basic components mounted on a vehicle: 1) electromagnetic (EM) induction sensor, 2) a global positioning system (GPS) receiver, 3) a computer, and 4) a hydraulic soil sampler. The EM sensor is placed in a plastic carrier-sled attached to the rear of the vehicle. The EM and GPS instruments are connected. The EM used in this study is the EM 38 dual dipole. The instrument operates at 14.6 kHz and has a fixed inter-coil spacing of 1 m.

The EM instrument's transmitter coil induces an electromagnetic field in the ground, which in turn creates a secondary magnetic field that is measured by the receiver coil. The ratio of primary and secondary electromagnetic fields provides a measure of the depth-weighted apparent electrical conductivity (EC) in a volume of soil's below both coils. The EM 38 device is operated in both horizontal and vertical positions at the soil surface to obtain effective measurements depth of 0.9 m and 1.8 m, respectively.

Along with the GPS data, the EM technique can provide geo-referenced distribution of soil EC. Since the EM measurements are relative, calibration of the data through soil sampling (as described below) is necessary to obtain absolute soil salinity values. Optimal sampling plans will be generated using the statistical package ESAP, specially developed to analyze the EM data (Lesch and Rhoades, 1999). Six sites characterizing the spatial distribution of salinity across the replicated micro-plots will be selected for calibration. At these sites, soil samples will be collected using an auger to a depth of 1.0 m. Samples will be analyzed for soil water content, EC,

and saturation percentage (SAR) following standard analytical methods (Gavlak, 2003; Rhoades, 1996). Soil salinity will then be estimated using ESAP and contour maps showing the salinity distribution within the micro-plot profiles will be generated with ArcGIS using the kriging interpolation or inverse-distance weighing interpolation. Maps of Se, B, Na, and Cl, will also be developed if good relationship exists between these parameters and the salinity estimates.

6.1.3. Monitoring of downward movement of ions and root growth by sampling

In supplement to the EM 38 surveys and related sampling, soil samples will be collected once every two weeks by auger at four depths (0-30, 30-60, 60-90, and 90-150 cm) for the duration of the experiment and from both planted and unplanted areas. Soil and root samples will be collected and analyzed for macro- and macronutrients, including Se, Cl, pH, and EC, as described below.

In addition, a pit will be dug in the planted and unplanted designated areas and a clean vertical soil profile will be cut. Along the profile, plant root distribution and pattern will be photographed and mapped (Centofanti et al. 2007) prior to soil and root sample collection.

6.1.4 Plant harvest

Above-ground young vegetative growth will be cut at 1-2 weeks intervals, as ‘agretti’ is consumed when young and tender and it regrows after the cuttings. Plant biomass and yield of the single cuttings will be measured. Shoot height will be measured weekly. Shoots will be separated into stems and leaves and analyzed separately.

6.1.5 Analysis of mineral elements

All samples will be acid digested with HNO_3, H_2O_2, and HCl as described by (Bañuelos and Akohoue 1994). Boron and macro- and micro-nutrients will be analyzed by an inductively-coupled plasma mass spectrometer (Agilent 7500cx, Santa Clara, USA) according to Agilent manufacture protocol. Chloride will be measured with the titrimeter using $AgNO_3$. For both *experiment 1 and 2*, all Se analyses, including Se speciation, will be performed by Bañuelos et al. at USDA in Parlier, in conjunction with their well-developed protocol for Se analysis using their high quality ICP-MS, as described in Bañuelos et al. (2011).

6.1.6 Analysis of antioxidants (total phenolics)

Organisms synthesize phenolic compounds in response to ecological pressures such as pathogens, insect attack, UV radiation, wounding, drought, salt and B stress. Increased synthesis of total phenolics in plants is a response of plants to protect themselves from ion-induced oxidative stress in case of high salinity, high B, or water stress. Phenolic compounds are ubiquitous on plants, and when plant-based foods are consumed, these phytochemicals contribute to intake of natural antioxidant in human diets. Hence, the second year of this study will analyze total phenolics in 'agretti' to determine if exposure to irrigation with drainage water influences the nutritional value of this crop when grown under these saline conditions. Total phenolics concentrations will be measured using the Folin-Ciocalteu reagent assay as described in Stushnoff et al. (2008). Measurements of total phenolics concentration is monitored at 756 nm and analyzed using a Spectra Max plus 384 spectrophotometer (Molecular Devices, Sunnydale, CA). Single phenolics will be analyzed by Liquid Chromatography coupled with mass spectrometer, if significant differences in total phenolics between treatments are observed.

6.1.7 Analysis of Se volatilization

The measurement of Se volatilization in this study will be conducted on the vegetated and bare plots with an open-through chamber system that has been developed by Professor's Terry laboratory (Lin et al., 1999) and applied in several other field studies (Bañuelos et al. 2005). The determination of the biological volatilization of Se in bare and vegetated plots will identify the impact that irrigation and plant species have on managing Se via volatilization deposited onto the soil via drainage water application.

Briefly, the chamber for volatile collection is made of 6.6 mm thick Plexiglas and has dimensions of 0.71 m long, 0.71 m wide, and 0.76 m high. The chamber encloses an area of 0.5 m^3 and an internal volume of 0.38 m^3. Volatile selenium is trapped in an alkaline peroxide trap solution (6% H_2O_2 and 0.05 M NaOH). The solutions are contained in a series of three 500 ml gas-washing bottles containing 200 ml of the trap solution. The gas-washing bottles are connected to the outlet port of each chamber and to each other with Teflon tubing. The volatile Se produced inside each chamber is captured by pulling air out of the chamber through the trap solution with a 1/3-hp vacuum pump. Solutions from three gas-washing bottles are collected and

taken to the lab for Se analysis (Lin et al. 2002; Lin et al. 1999). The volatilization rate is calculated with a flux unit (mg Se m^{-2} d^{-1}) over a ground surface area in the field.

6.2 Experiment 2

6.2.1 Description of mesocosm study at UC Berkeley

Professor Terry has over 15 years of experience and extensive expertise in the use of wetlands for Se removal from saline and non-saline waters. As visiting scholar at UCB, Dr. Zhu has been working on wetland strategies and excessive nutrients and heavy metal removal for over 10 years in China. In association with Prof. Terry, she brings her expertise into co-designing a wetland strategy with 'agretti' for removing excessive B and Se via rhizofiltration from saline drainage water.

The mesocosms are made of 12 plastic tanks, each being 108 × 52 × 46 cm 3 in size. Pumps (Sunterra 104506) and rubber tubing (9 mm id, 15 mm od, 3 mm w; Fisher Scientific) will be set up to circulate water (3.15×10^{-5} m^3 s^{-1}) from the mesocosm outlet back to the inlet (Fig. 6). Porous PVC pipes (12 cm long, 8 cm in dia) are installed at the outlet and inlet of each mesocosm and equipped with a pump and tubing to facilitate the recirculation of the aqueous solution. The mesocosm studies will be conducted in an environment-controlled greenhouse with 25/22°C day/night temperatures, 16 h photoperiod, 1000 µE (photo-synthetic photonflux) m^{-2} s^{-1}, located at UC Berkeley.

6.2.2. Plant growth in mesocosm study

For the first part of this study, 12 mesocosms will be filled to a depth of 15 cm with a substrate of peat moss and sand (1:1 v:v, acid-washed sand/peat moss). After addition of tap water, the substrate attains a final depth of 12 cm. 'Agretti' used in this experiment will be germinated in trays and grown for one month before transplanting into the mesocosm. Plants will be grown for 14 days in half-strength Hoagland's solution (with a B concentration of 0.5 mg L^{-1}) before being transferred into the treatment mesocosm (Fig. 6). During the first year of the proposed project, the drainage water used in the mesocosm wetland system will simulate typical average Se and B concentrations and salinity in drainage water presently produced at Red Rock Ranch. Indicatively, the synthetically constructed drainage water will have a B concentration of 7 mg L^{-1}, sulfate salinity electrical conductivity (EC) of 10 dS m^{-1}, and Se concentration of 0.25

mg L^{-1}. Boron will be added as boric acid H_3BO_3 and the Se as sodium selenate Na_2SeO_4. No additional Se and B will be added into the circulating drainage water within the mesocosm after the initial injection. The plants will be grown for about 16 weeks. The nutrient solution will be replenished on a weekly basis by adding half-strength Hoagland's solution to each mesocosm. Synthetic drainage water without B and Se will be added to maintain a water depth of 12 cm and to replace losses due to evapotranspiration. Water samples will be collected periodically from outlet pipe and analyzed for Se and B. In this experiment, the growth, Se and B uptake and partitioning, and Se and B removal efficiency will be determined for 'agretti'.

Plants from three different mesocosm or 3 replicates will be harvested at 5 weeks, 10 weeks, and 16 weeks, respectively (three replicates will also be harvested at the beginning of the experiment to provide data for the zero time-point). The study will be repeated in the second year after analysis of first year samples have been performed. During the second year of the proposed project we will test 'agretti's' tolerance to increased concentrations of B and salinity in the mesocosm wetland system and evaluate 'agretti's' ability to remove B and Se from the circulating drainage water. In this regard, two drainage solutions with varying salinity and B levels will be used: 1) EC of 15 dS m^{-1}, 8 mg B L^{-1}, 0.25 mg Se L^{-1}; and 2) EC of 20 dS m^{-1}, 10 mg B L^{-1}, 0.25 mg Se L^{-1}. The salinity, B and Se levels used in this study are similar to those used by Bañuelos et al. (1999) and Shannon et al. (1999).

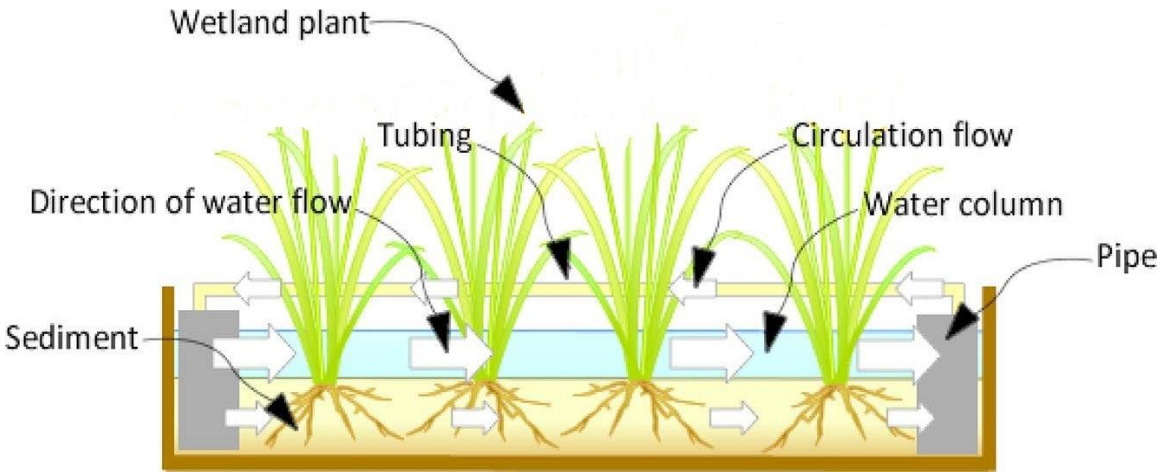


Figure 6. Schematic showing mesocosm with wetland plants growing in sand-peat moss substrate. Drainage water is constantly recirculated through the mesocosm (adapted from Huang et al. (2013).

Water samples will be periodically collected and analyzed for B and Se levels and water levels within each mesocosm will be maintained, as described above. At harvest, the plants will be separated into shoot tissue (i.e., plant material including stems, leaves, and any inflorescences) and root tissue and analyzed for mineral elements and for the type of chemical forms in which Se is stored in the shoots (Se speciation), as already described above. All analyses of mineral elements (described in section 6.1.5) and antioxidants (described in section 6.1.6) and periodic Se volatilization measurements (described in section 6.1.7) will be performed similarly as described in experiment 1.

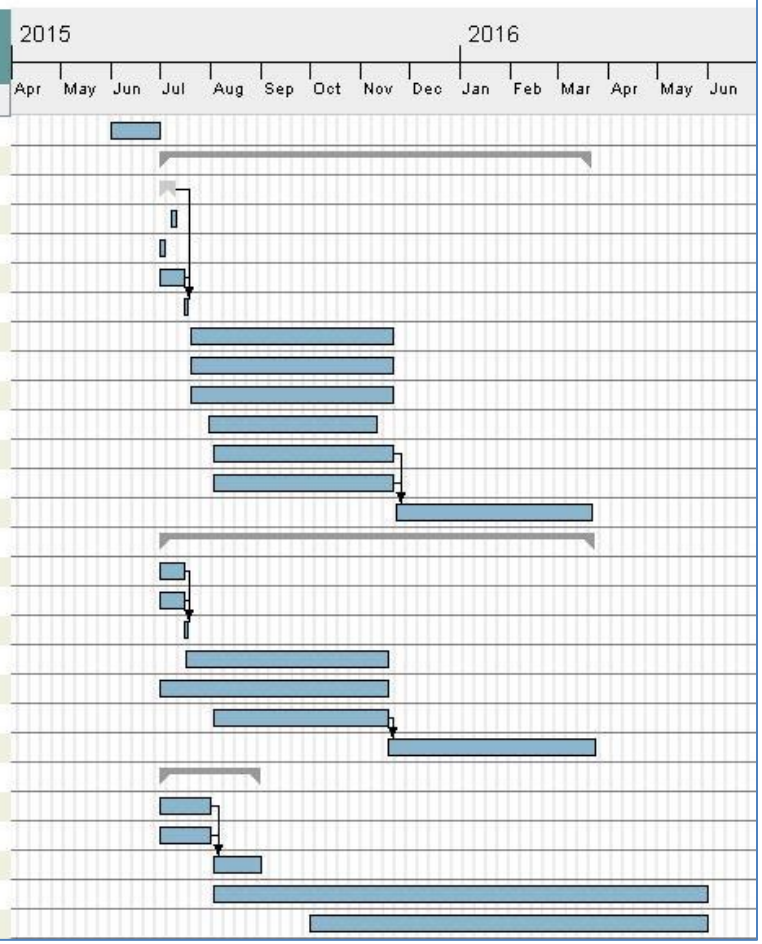
6.3 Economic analysis

The economic output will use stated and revealed preference data from a choice-based conjoint survey instrument to estimate consumers' willingness to pay (WTP) for 'agretti' produced under saline agriculture growing conditions. The sampling design will account for demand from representative consumption groups, and therefore includes selective shoppers (e.g. Whole Foods market) and the general population (e.g. Savemart). The survey will be administered to respondents in the markets as detailed before. We use choice-based conjoint analysis [CA] to estimate consumer WTP for 'agretti' produced under saline agriculture growing conditions. More generally, the survey estimates WTP for produce when information is available for specific production practices. This method typically uses a survey instrument, and the WTP measure is elicited from a hypothetical market scenario (Green and Srinivasan 1990). The values elicited using stated preference data alone may not reflect actual market transactions and therefore we plan to supplement these measures with data from an incentive compatible economic experiment in some of the identified markets (List and Gallet 2001). Our approach involves presenting shoppers with a simple choice involving the produce and money. We plan to administer the survey via tablet computers for convenience and speed (the complete interaction with the respondent is expected to be less than 10 minutes). We will use econometric models (conditional logit) to estimate the WTP for produce based on its attributes, and use STATA software for the data analysis.

7. Schedule

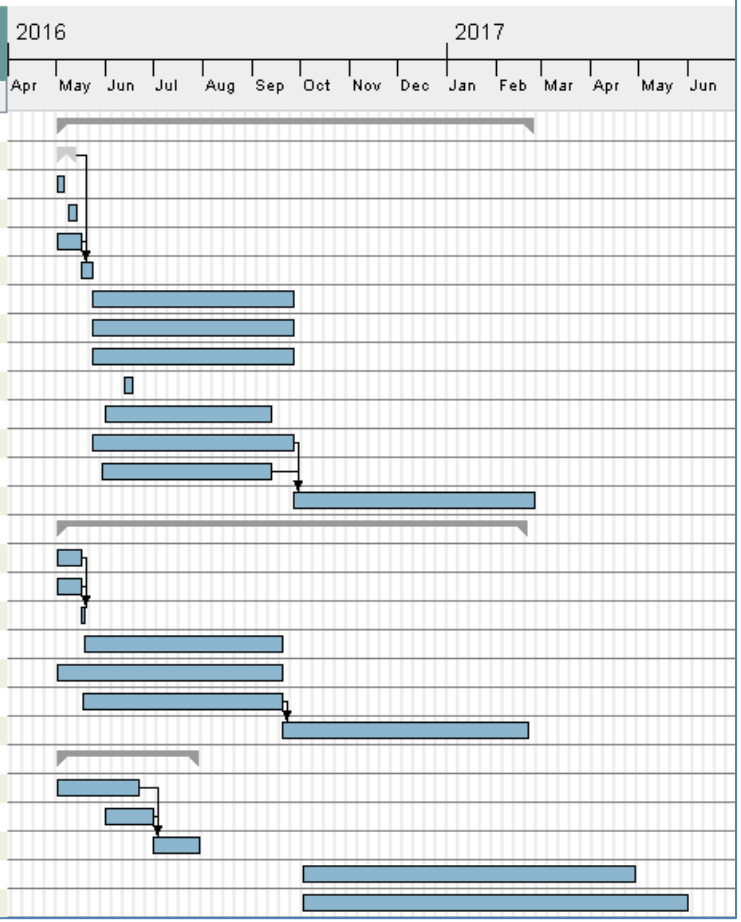
7.1 Schedule for year 1 – Project development

Name	Begin date	End date
Preparation of documents for compliance with CEQA	6/1/15	6/30/15
Development and execution of micro-plot study year 1	7/1/15	3/21/16
Field preparation	7/1/15	7/10/15
Installation of irrigation system	7/8/15	7/10/15
Herbicides application	7/1/15	7/3/15
Seed germination	7/1/15	7/15/15
Transplant of seedlings into micro-plots	7/16/15	7/17/15
Monitor plant growth	7/20/15	11/20/15
Maintain operation of drip-irrigation system	7/20/15	11/20/15
Control weeds, gophers, and rabbits	7/20/15	11/20/15
Execution of EM 38 imagery	7/31/15	11/10/15
Collection of soil and plant samples	8/3/15	11/20/15
Analysis of soil profile	8/3/15	11/20/15
Samples processing and analysis	11/23/15	3/21/16
Development and execution of mesocosm wetland system study year 1	7/1/15	3/23/16
Seed germination - mesocosm study	7/1/15	7/15/15
Preparation of mesocosm and experiment set-up	7/1/15	7/15/15
Transplant of seedlings into mesocosm	7/16/15	7/17/15
Monitor plant growth	7/17/15	11/17/15
Maintain operation of mesocosm wetland system	7/1/15	11/17/15
Collection of water and plant samples	8/3/15	11/17/15
Samples processing and analysis	11/18/15	3/23/16
Development and execution of economic analysis - year 1	7/1/15	8/31/15
Establishment of contact with supermarkets	7/1/15	7/31/15
Preparation of questionnaire	7/1/15	7/31/15
Delivery and execution of survey to consumers	8/3/15	8/31/15
Data analysis - year 1	8/3/15	5/31/16
Preparation of scientific publications	10/1/15	5/31/16



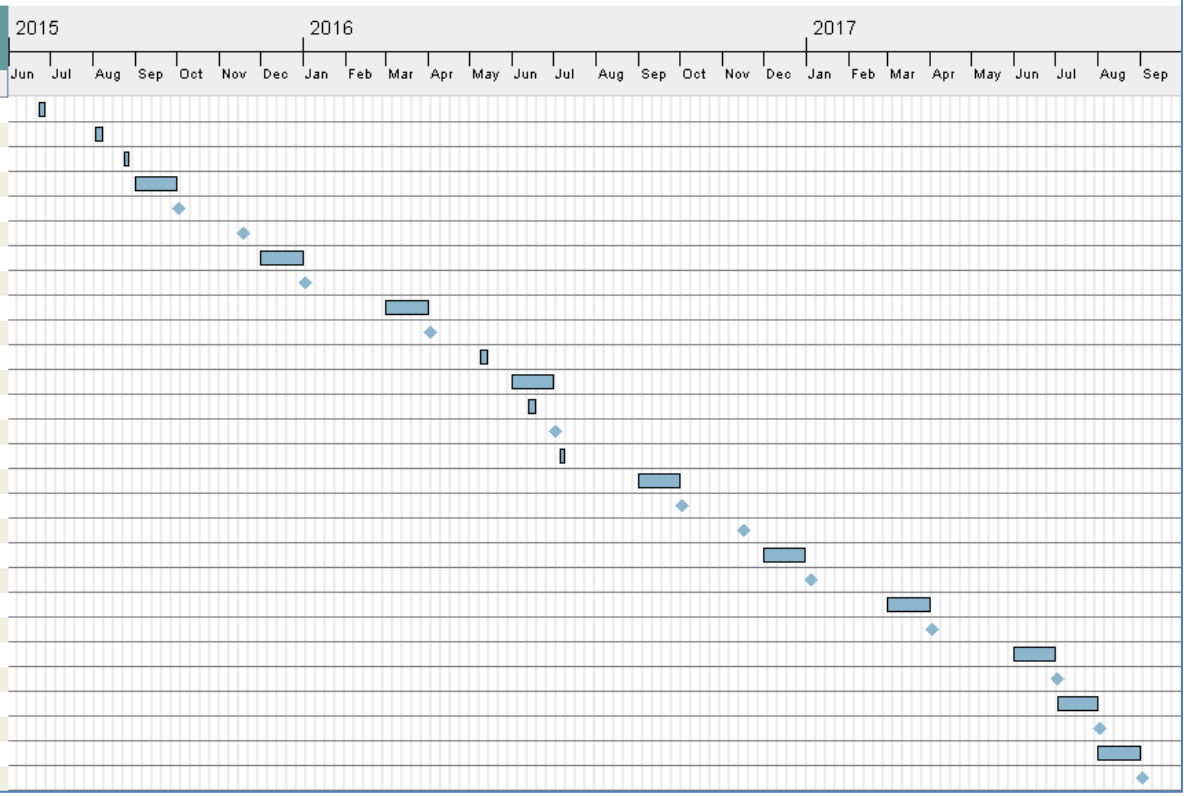
7.2 Schedule for year 2 – Project development

Name	Begin date	End date
Development and execution of micro-plot study year 2	5/2/16	2/24/17
Field preparation	5/2/16	5/13/16
Herbicides application	5/2/16	5/5/16
Re-establishment of beds	5/9/16	5/13/16
Seed germination	5/2/16	5/16/16
Transplant of seedlings into micro-plots	5/17/16	5/23/16
Monitor plant growth	5/24/16	9/26/16
Maintain operation of drip-irrigation system	5/24/16	9/26/16
Control weeds, gophers, and rabbits	5/24/16	9/26/16
Field demonstration	6/13/16	6/17/16
Execution of EM 38 imagery	6/1/16	9/12/16
Collection of soil and plant samples	5/24/16	9/26/16
Analysis of soil profile	5/30/16	9/12/16
Samples processing and analysis	9/27/16	2/24/17
Development and execution of mesocosm wetland system study - year 2	5/2/16	2/20/17
Seed germination - mesocosm study	5/2/16	5/16/16
Preparation of mesocosm and experiment set-up	5/2/16	5/16/16
Transplant of seedlings into mesocosm	5/17/16	5/18/16
Monitor plant growth	5/19/16	9/19/16
Maintain operation of mesocosm wetland system	5/2/16	9/19/16
Collection of water and plant samples	5/18/16	9/19/16
Samples processing and analysis	9/20/16	2/20/17
Development and execution of economic analysis - year 2	5/18/16	7/29/16
Renew contact with supermarkets	5/2/16	6/21/16
Edit and review questionnaire	6/1/16	6/30/16
Delivery and execution of survey to consumers	7/1/16	7/29/16
Data analysis - year 2	10/3/16	4/28/17
Preparation of scientific publications	10/3/16	5/31/17



7.3 Schedule for year 1 and 2 – Meetings, deliverables, and milestones

Name	Begin date	End date
Visit of Dr. Zhu to Parlier	6/23/15	6/26/15
Visit of Dr. Centofanti to UC Berkeley	8/3/15	8/7/15
Visit of Dr. Zhu to Parlier	8/24/15	8/26/15
Preparation of quarterly report - year 1	9/1/15	9/30/15
Delivery of quarterly report	9/30/15	9/30/15
Meeting for data sharing and discussion	11/16/15	11/16/15
Preparation of quarterly report - year 1	12/1/15	12/31/15
Delievery of quarterly report	12/31/15	12/31/15
Preparation of quarterly report - year 1	3/1/16	3/31/16
Delivery of quarterly report	3/31/16	3/31/16
Visit of Dr. Zhu to Parlier	5/9/16	5/13/16
Preparation of quarterly report - year 1	6/1/16	6/30/16
Visit of Dr. Zhu to Parlier	6/13/16	6/17/16
Delivery of quarterly report	6/30/16	6/30/16
Visit of Dr. Centofanti to UC Berkeley	7/6/16	7/8/16
Preparation of quarterly report - year 2	9/1/16	9/30/16
Delivery of quarterly report	9/30/16	9/30/16
Meeting for data sharing and discussion	11/14/16	11/14/16
Preparation of quarterly report - year 2	12/1/16	12/30/16
Delivery of quarterly report	1/2/17	1/2/17
Preparation of quarterly report - year 2	3/1/17	3/31/17
Delivery of quarterly report	3/31/17	3/31/17
Preparation of quarterly report - year 2	6/1/17	6/30/17
Delivery of quarterly report	6/30/17	6/30/17
Preparation of final report	7/3/17	7/31/17
Delivery of final report	7/31/17	7/31/17
Preparation of post-completion report	8/1/17	8/31/17
Delivery of post-completion report	8/31/17	8/31/17



8. Budget

8.1 Budget narrative

We request $258,390 in grant amount for two years to cover the following components: personnel, fringe benefits, supplies, travel, and administrational costs. In the next paragraphs we provide a detailed budget narrative of the grant amount requested (section 8.1.2) and of the federal contributions (section 8.1.3).

8.1.2 Budget narrative for grant amount requested

A. Personnel

1. Project director: *Dr. Zolodske*'s role in the project is described in section 2. *Dr. Zolodske* will spend about 1% of his time (equal to 20 hours/per year @ $82/hr.) on this project and his salary will be covered by the grant amount requested for the 2 years of the contract. Compensation amounts to $1,640/year x two years = $3,280 (salary does not includes benefits, see section B below)
2. Principal investigator: *Dr. Centofanti*'s role in the project is described in section 2. *Dr. Centofanti* will spend about 50% (equal to 1045 hours/per year @ $40/hr.) of her time on this project and her salary will be covered by the grant amount requested for the 2 years of the contract. Compensation amounts to $41,800/year x two years = $83,600 (salary does not includes benefits, see section B below)
4. Co-Principal investigator: *Dr. Cassel*'s role in the project is described in section 2. *Dr. Cassel* will spend about 15% (equal to 300 hours/per year @ $40/hr.) of her time on this project and her salary will be covered by the grant amount requested for the 2 years of the contract. Compensation amounts to $12,000/year x two years = $24,000 (salary does not includes benefits, see section B below)
3. Cooperator, *Mr. Murugesan*'s role in the project is described in section 2. *Mr. Murugesan* will spend about 5% (equal to 100 hours/per year @ $40/hr.) of his time on this project and his salary will be covered by the grant amount requested for the 2 years of the contract. Compensation amounts to $4,000/year x two years = $8,000 (salary does not includes benefits, see section B below)
4. Other key personnel, *Mr. Perez*'s role in the project is described in section 2. *Mr. Perez* will spend about 62% (equal to 643 hours/per year @ $15/hr.) of his part-time on this project and his salary will be covered by the grant amount requested for the 2 years of the

contract. Compensation amounts to $9,645/year x two years = $19,290 (salary does not includes benefits, see section B below)

5. Other key personnel, *Mr. King*'s role in the project is described in section 2. *Mr. King* will spend about 30% (equal to 315 hours/per year @ $15/hr.) of his part-time on this project and his salary will be covered by the grant amount requested for the 2 years of the contract. Compensation amounts to $4,725/year x two years = $9,450 (salary does not includes benefits, section B below)

5. Other key personnel, *Mr. Touyee Thao*'s role in the project is described in section 2. *Mr. Taho* will spend about 30% (equal to 650 hours/per year @ $15/hr.) on this project and his salary will be covered by the grant amount requested for the 2 years of the contract. Compensation amounts to $9,750/year x two years = $19,500 (salary does not includes benefits, section B below)

B. Fringe benefits

Fringe benefits are calculated for two years and only for the time devoted to the project.

1. *Dr. Zoldoske:* $3,280 (compensation for time devoted to the project) x 11% (fringe benefit) = $361. Benefits include FICA @ 6.2%, health/life insurance @ 4.8%

2. Dr. Centofanti: $83,600 (compensation for time devoted to the project) x 11% (fringe benefit) = $9,196. Benefits include FICA @ 6.2%, health/life insurance @ 4.8%

3. *Dr. Cassel:* $24,000 (compensation for time devoted to the project) x 11% (fringe benefit) = $2,640. Benefits include FICA @ 6.2%, health/life insurance @ 4.8%

4. *Mr. Murugesan:* $8,000 (compensation for time devoted to the project) x 11% (fringe benefit) = $880. Benefits include FICA @ 6.2%, health/life insurance @ 10%, worker comp @ 3.8%

5. *Mr. Baudelio Perez:* $19,290 (compensation for time devoted to the project) x 11%(fringe benefit) = $2,122. Benefits include FICA @ 6.2%, health/life insurance @ 4.8%

6. *Mr. King:* $9,450 (compensation for time devoted to the project) x 8% (fringe benefit) = $756. Benefits include FICA @ 6.2% and worker comp @ 1.8%

7. *Mr. Thao:* $19,500 (compensation for time devoted to the project) x 11% (fringe benefit) = $2,145. Benefits include FICA @ 6.2%, health/life insurance @ 4.8%

C. Supplies

a) Micro-plot study:

I. Field preparation:

Herbicide: Clethodim herbicide (3 gallons) 2 @ $312 = $624

Loc sleeves couplers, 300 @ $0.51 = $153

Coupler compressors 70, 300 @ $0.57 = $171

Drip emitters, 300 @ $0.20 = $60

Echo trimmer line, 10 @ $15 = $150

Echo trimmer oil, 4 @ $9 = $36

Clamps, 10 @ $1= $10

Bell valve PVC 3", PVC cement, PVC primer, coupling reducer Schedule 40= $84

Shovels, 4 @ $10 = $40

Dewal 300 foot measure = $30

Irrigation pump parts and oil = $392

Total: $1,750/year x 2 years= $3,500

II. Seed purchase: 28 packs @ $10/pack = $280

III. Seed germination costs: $500/year x 2 years = $1,000

IV. EM 38 remote sensing technology costs:

Sensors maintenance costs, GPS tracker, ULTRALIFE 9-volt Lithium batteries = $1,000

Office and computer supplies (binders, file folders, printer paper, toners, staples, flash drives, CDs, software license (Sigmaplot, Origin, etc.): = $500

Laboratory supplies (freezer bags 1 pk @ $32, storage bags 1 pk @ $30, paper bags 1 pk @ $46; laboratory nitrile gloves 1 pack @ $15; 3.8 L HDPE jugs for waste storage 1 @ $13, 30 oz translucent cups 1@ $2.25, plastic bottles 1 @ $10) = $1,000

Total: $2,500/year= $5,000

V. Samples, collection, processing and analysis:

Chemical reagents (HNO_3, H_2O_2, and HCl, $AgNO_3$, Folin-Ciocalteu reagent, methanol, HPLC grade water, gallic acid, salts, NIST standards, etc.) = $ 2,000

Pipette tips (10-200 µL tips case of 1,000 @ $20; 200 µL 3 bulk packs @ $150, 1mL tips case of 1,000 @ $30, 50 mL eppendorf tips 100 bulk pack @ $115) = $300

Laboratory nitrile gloves (1 pack @ $15), 10 packs = $150

Tubes (20 mL polypropylene tubes 200 pk @ $112; microcentrifuge tubes 500 pk @ $28; 50 mL digestion vessels with screw cap 500 pk @ $141) = $310

Glassware (volumetric flasks, cylinders and beakers, 1 @ $10) = $100

Gas-washing bottles for analysis of selenium volatilization (1 gas-washing bottle @ $500) = $2,000

Agilent 2 mL screw top amber vials (100 pk @ $230) = $690

Syringe filters 0.2 µM (50 pk @ $58) = $232

Syringe only slip (10 mL vol 100 pk @ $25) = $100

Buckets and plastic containers (3.8 L HDPE jugs for waste storage 1 @ $13, 30 oz translucent cups 1 @ $2.25, plastic bottles 1 @ $10) = $200

Oil inland 45 for vacuum pump, 1 @ $118 = $118

Bags for plant and soil sampling (freezer bags 1 pk @ $32, storage bags 1 pk @ $30, paper bags 1 pk @ $46) = $300

Total: $6,500/year x 2 years =$13,000

VI. Argon gas ($400/tank x 4 tanks/year x 2 years) = $3,200

b) Mesocosm wetland system:

I. Seed purchase: 14 packs @ $10/pack = $140

II. Greenhouse and wetland mesocosm supplies:

Fluorescent lamp bulbs (1 @ $300) = $2,000

Shade cloths (20’ x 20’ @ $130) = $600

Commercial shutter fan (1 @ $125) =$250

Tanks and lids (1 set @ $33): $400

PVC evaporative pad for cooling system: $550

Tubing, PVC fitting, clamps = $100

Flats, potting soil, gloves, spatulas, spoons, etc.: $100

Total: $4,000/year x 2 years = $8,000

V. Samples, collection, processing and analysis:

Chemical reagents (HNO_3, H_2O_2, and HCl, $AgNO_3$, methanol, HPLC grade water, salts, NIST standards, etc.) = $ 2,000

Pipette tips (10-200 µL tips case of 1,000 @ $20; 200 µL 3 bulk packs @ $150, 1mL tips case of 1,000 @ $30, 50 mL eppendorf tips $115) = $300

Laboratory nitrile gloves (1 pack @ $15), 10 packs = $150

Tubes (20 mL polypropylene tubes 200 pk @ $112; microcentrifuge tubes 500 pk @ $28; 50 mL digestion vessels with screw cap 500 pk @ $141) = $350

Glassware (volumetric flasks, cylinders and beakers, 1 @ $10) = $100

Bags for plant and soil sampling (freezer bags 1 pk @ $32, storage bags 1 pk @ $30, paper bags 1 pk @ $46) = $100

Total: $3,000/year x 2 years =$6,000

VI. Argon gas ($400/tank x 3 tanks/year x 2 years) = $2,400

c) Economic study:

I. Stationary and computer: binders, file folders, printer paper, toners, staples, flash drives, CDs: $100

Library's and publications downloads fees, software license (STATA, etc.): $150

Total: $250/year x 2 years = $500

D. Travel

1. Trips to/from micro-plot field study and USDA in Parlier for development and execution of micro-plot study: 100 miles retour x 52 trips (26 trips/year) x $0.56/mile = $2,912
2. Trips to/from micro-plot field study and CIT in Fresno for development and execution of micro-plot study: 104 miles retour x 40 trips (20 trips/year) x $0.56/mile = $2,330
3. Trips to/from USDA in Parlier, UC Berkeley, and CIT in Fresno for meetings amongst the team members: 8 trips x $500/trip = $4,000

   Lodging: $150/night x 2 nights = $300

   Per diem: $50/day x 2 days = $100

   Travel: $0.5/mile x 200 miles (Berkeley to Parlier) = $100
4. Trips to/from Santa Cruz, San Francisco, and Fresno for delivery and execution of economic survey: 2 trips/year @ $375/trip; $750/year x 2 years = $1,500

E. Administrative costs

1. Administrational assistance performed by Ellen Suryadi at CIT Fresno to prepare invoices, carry our project paperwork, and prepare pay slips for Dr. Cassel, Dr. Centofanti, Mr. King, Mr. Murugesan, Mr. Perez, Mr. Thao, and Dr. Zoldoske (120 hr. at $30/hr. +11% benefit x 2 years)= $7,992.
2. Overhead administrational costs required by CSU Fresno Foundation ($246,086 total budget @ 5% of total budget) = $12,304

8.1.3 Budget narrative for federal contributions

A. Personnel

1. Project manager: *Dr. Bañuelos*'s role in the project is described in section 2. *Dr. Bañuelos* will spend about 20% (equal to 400 hours/per year) of his time on this project and his salary will be covered by federal funds for the 2 years of the contract. Compensation amounts to $30,000/year x two years = $60,000 (salary includes benefits)

B. Field and laboratory expenses

1. Micro-plot study and mesocosm wetland system (costs covered by federal and UCB funds):

   I. Irrigation system maintenance and repair at Red Rock Ranch: $3,000 year x 2 years = $6,000

   II. Analytical instruments operational costs and repairs at USDA and UCB: $7,500/year x 2 years =$15,000

8.2.1 Budget summary of project costs for two years –grant amount requested

Task	*Grant amount requested ($)*	*Total costs ($)*
Personnel (compensation including fringe benefits)		
Micro-plot study: field preparation	599 (Mr. Perez)	599
Micro-plot study: transplanting	1,665 (Mr. Perez) 810 (Mr. King)	2,475
Micro-plot study: development and execution, including field demonstration	6,660 (Mr. Perez) 22,200 (Dr. Centofanti) 3,240 (Mr. King)	32,100
Micro-plot study: analysis of soil profile	4,163 (Mr. Perez) 11,100 (Dr. Centofanti) 2,106 (Mr. King)	17,369
Micro-plot study: samples collection and processing	8,325 (Mr. Perez) 22,200 (Dr. Centofanti) 4,050 (Mr. King)	34,575
Micro-plot study: EM 38 remote sensing surveys	26,640 (Dr. Cassel) 21,645 (Mr. Thao)	48,285
Micro-plot study: samples analysis with ICP and LC-MS	8,880 (Dr. Centofanti)	8,880
Micro-plot study: data analysis and quarterly, final, and post-completion report preparation	28,416 (Dr. Centofanti)	28,416
Economic study: establishment of contact with supermarkets	1,776 (Mr. Murugesan)	1,776
Economic study: preparation of questionnaire	2,664 (Mr. Murugesan)	2,664
Economic study: data analysis and quarterly report preparation	3,552 (Mr. Murugesan)	3,552
Supplies		
Micro-plot study: field preparation	3,500 (irrigation supplies, herbicides, etc.)	3,500
Micro-plot study: seed purchase and germination	280 (seeds) 1,000 (seedlings are germinated at localTransplanters)	1,280
Micro-plot study: EM 38 remote sensing technology	5,000 (sensors, computer supplies, GPS supplies, etc.	5,000
Micro-plot study: samples collection, processing, and	13,000 (laboratory supplies) 3,200 (Argon gas)	16,200

analysis (including purchase of argon gas)		
Mesocosm study: development and execution, including seed purchase	8,000 (greenhouse and mesocosm supplies) 140 (seed purchase)	8,140
Mesocosm study: samples collection, processing, and analysis (including purchase of argon gas)	6,000 ((laboratory supplies) 2,400 (Argon gas)	8,400
Economic study: data collection and analysis	500	500
Travel		
Micro-plot study: Transplanting, development and execution and EM 38 remote sensing technology	2,912 (trips to/from micro-plot field study and USDA in Parlier) 2,330 (trips to/from micro-plot field study and CIT in Fresno)	5,242
Economic study: survey execution and data collection	1,500 (trips to/from Santa Cruz, San Francisco, and Fresno)	1,500
Meetings, data sharing, communication amongst project team members	4,000 (trips to/from USDA in Parlier, UC Berkeley, and CIT in Fresno)	4,000
Administrational costs		
Administrational costs	7,992 (Ms. Suryadi) 3,641 (Dr. Zoldoske)	11,633
Total sum of costs		246,086
Overhead costs	@ 5% of total (CSU Fresno Foundation)	12,304
Total grant amount requested		**258,390**

8.2.2 Budget summary of project costs for two years –federal contributions

Task	*Grant amount requested ($)*	*Total costs ($)*
Personnel		
Supervising all research activities and reviewing all reports preparation	Dr. Bañuelos	40,000
Organization, data sharing, and project management	Dr. Bañuelos	20,000
Maintenance and operating expenses		
Micro-plot study: irrigation system maintenance and repair	6,000	6,000
Micro-plot study and mesocosm study analytical instruments operational costs and repairs	15,000	15,000
Total federal funds		**81,000**

9. Deliverables

Project deliverables include quarterly reports, final report, post-completion report, and invoices. A detailed explanation of deliverables related to the specific tasks and time schedule planned for each deliverable is shown in section 5. In addition, scientific publications will be produced and submitted to peer-reviewed top journals in the area of environmental management, water pollution, and soil and plant sciences. Field demonstration will be performed in the second year of the project.

10. References

Ayars J E and Soppe R W O 2014 Integrated on-farm drainage management for drainage water disposal. Irrigation and Drainage 63, 102-111.

Ayars J E, Hanson B R, Mirzaw B 2013 The San Joaquin Valley: 20 years later. 7th International Conference on Irrigation and Drainage. Using 21st Century technology to better manage iIrrigation water supplies. Wahlem B T, Anderson S S (Eds.).

Bañuelos G S and Akohoue S 1994 Comparison of microwave digestion with block digestion for selenium and boron analysis in plant tissues. Communications in Soil Science and Plant Analysis 25, 1655-1670.

Bañuelos G S, Fakra S C, Walse S S, Marcus M A, Yang S I, Pickering I J, Pilon-Smits E A H and Freeman J L 2011 Selenium accumulation, distribution, and speciation in spineless prickly pear cactus: A drought- and salt-tolerant, selenium-enriched nutraceutical fruit crop for biofortified foods. Plant Physiology 155, 315-327.

Bañuelos G S, Lin Z Q, Arroyo I and Terry N 2005 Selenium volatilization in vegetated agricultural drainage sediment from the San Luis Drain, Central California. Chemosphere 60, 1203-1213.

Bañuelos G S, Shannon M C, Ajwa H, Draper J H, Jordahl J and Licht L 1999 Phytoextraction and accumulation of boron and selenium by poplar (Populus) hybrid clones. International Journal of Phytoremediation 1, 81-96.

Cassel S F and Zoldoske D 2006 Assessing canal seepage and soil salinity using the electromagnetic remote sensing technology. WIT Transactions on Ecology and the Environment 96, 55-63.

Centofanti T and Bañuelos G S 2014 Evaluation of the halophyte Salsola Soda as an alternative crop for saline sols high in selenium and boron. Submitted to Journal of Environmental Management (December 2014).

Centofanti T, Frossard E and Flühler H 2007 Time-dependent distribution of surface-applied radionuclides and their recovery in maize during the growing season. Journal of Environmental Quality 36, 280-290.

Cevinka V, Diener J, Finch C, Martin M, Messezes F, Peters D, Shelton J 1999 Integrated System for Agriculutral Drainage Management in Irrigated Farmland. Bureau of Reclamation, U.S. Dept. of the Interior, Final Research Report 4FG-7—11920.41.

Flowers T J and Colmer T D 2008 Salinity tolerance in halophytes. New Phytologist 179, 945-963.

Gavlak R, Horneck D, Miller R O, and Kotuby-Amacher J 2003 Soil, plant and water reference methods for the western region. WREP-125, 2nd edition, Oregon State Univeristy, Corvallis, OR.

Grattan S R, Oster J D, Letey J, Kaffka S R 2014 Drainage Water reuse: Concepts, practices and potential crops. In: Salinity and Drainage in the San Joaquin Valley, California. Science Technology, and Policy. Chang A C, Selva D B (Eds.). Springer Verlag, Dordrecht, Heidelberg, New York, London. pp.277-302.

Green PE and Srinivasan V 1990 Conjoint Analysis in Marketing: New Developments with Implications for Research and Practice Journal of Marketing 54(4), 3–19.

Huang J C, Suárez M C, Yang S I, Lin Z Q and Terry N 2013 Development of a constructed wetland water treatment system for selenium removal: Incorporation of an algal treatment component. Environmental Science and Technology 47, 10518-10525.

Lesch S M, and Rhoades J D 1999 ESAP-95 Software Package Version 2.01R. USDA-ARS, George E. Brown Jr. Salinity Laboratory, Riverside, CA.
Lin Z Q, Cervinka V, Pickering I J, Zayed A and Terry N 2002 Managing selenium-contaminated agricultural drainage water by the integrated on-farm drainage management system: Role of selenium volatilization. Water Research 36, 3150-3160.
Lin Z Q, Hansen D, Zayed A and Terry N 1999 Biological selenium volatilization: Method of measurement under field conditions. Journal of Environmental Quality 28, 309-315.
List JA and Gallet C 2001 What Experimental Protocol Influence Disparities between Actual and Hypothetical Stated Values? Evidence from a Meta-Analysis Environmental and Resource Economics 20(3),241–254.
Oster J D, Sheinberg J, Abiol J P 1999 In: Agricultural Drainage. Skaggs R W, Van shilfgaarde J (Eds.). Agronomy Monogram ASA, CSA, SSSA. Madison, WI. pp: 659-694.
Oster J D and Grattan S R 2002 Drainage water reuse. Irrigation and Drainage Systems 16, 297-310.
Panta S, Flowers T, Lane P, Doyle R, Haros G and Shabala S 2014 Halophyte agriculture: Success stories. Environmental and Experimental Botany 107, 71-83.
Rhoades J D 1996 Salinity: Electrical conductivity and total dissolved salts. In: Methods of Soil Analysis, Part 3 Chemical Methods. Sparks D L (Eds.). American Society of Agronomy, Madison, WI.
Rhoades J D 1999 Use of Saline Drainage Water for Irrigation. In: Agricultural Drainage. Skaggs R W, Van shilfgaarde J (Eds.). Agronomy Monogram ASA, CSA, SSSA. Madison, WI. pp: 615-658.
Rozema J and Schat H 2013 Salt tolerance of halophytes, research questions reviewed in the perspective of saline agriculture. Environmental and Experimental Botany 92, 83-95.
Shannon M C, Bañuelos G S, Draper J H, Ajwa H, Jordahl J and Licht L 1999 Tolerance of hybrid poplar (Populus) trees irrigated with varied levels of salt, selenium, and boron. International Journal of Phytoremediation 1, 273-288.
Suyama H, Benes S E, Robinson P H, Getachew G, Grattan S R and Grieve C M 2007 Biomass yield and nutritional quality of forage species under long-term irrigation with saline-sodic drainage water: Field evaluation. Animal Feed Science and Technology 135, 329-345.
Stushnoff C, Holm D, Thompson M, Jiang W, Thompson H, Joyce N and Wilson P 2008 Antioxidant properties of cultivars and selections from the colorado potato breeding program. American Journal of Potato Research 85, 267-276.
Tundis R, Menichini F, Conforti F, Loizzo M R, Bonesi M, Statti G and Menichini F 2009 A potential role of alkaloid extracts from Salsola species (Chenopodiaceae) in the treatment of Alzheimer's disease. Journal of Enzyme Inhibition and Medicinal Chemistry 24, 818-824.
Watson M C, Bañuelos G S, O'Leary J W and Riley J J 1994 Trace element composition of Atriplex grown with saline drainage water. Agriculture, Ecosystems and Environment 48, 157-162.

Appendix A

CVs of all project team members are enclosed in this section

DAVID F. ZOLDOSKE
davidzo@csufresno.edu
559/278-2066

AREAS OF EXPERTISE:

Program Leadership	**Technology Testing & Evaluation**
Educational Development	**Agricultural Resource Issues**

EDUCATION:

Ed.D. Leadership	University of La Verne	La Verne, CA
M.S. Agriculture	California State University, Fresno	Fresno, CA
B.S. Agricultural Business	California State University, Fresno	Fresno, CA

EXPERIENCE:

2008-Present **Executive Director**, Water Resources and Policy Initiatives (WRPI), California State University, Office of the Chancellor, Long Beach. Responsibilities include representing the California State University system on water issues within California. Activities include facilitating CSU faculty research efforts with water priorities within the State.

1994- Present **Director**, Center for Irrigation Technology (CIT), California State University, Fresno. Key mission of the CIT is to advance water use efficiency in irrigation. The position requires administration of all aspects of the management for the Center, including: planning and budgeting; promotion and public relations with community and industry; liaison with an advisory board; provide educational opportunities to the public; development of contracts and grants for applied research; hiring and supervision of staff; and training and publications efforts.

1993- Present **Lecturer/Adjunct Faculty**, Department of Plant Science, College of Agricultural Sciences and Technology, California State University, Fresno and Department of Agriculture, College of Sequoias. Developed and taught classes at both the community college and university level.

HONORS AND RECOGNITION:

Senior Fellow, California Council on Science and Technology, 2012.

Recognized nationally as one of 18 Environmental Stewards and Innovators in the Golf Industry by the Golfweek's Superintendent NEWS, October 26th, 2001.

Honorary Life Membership in the American Society of Irrigation Consultants, May 2001.

National Water and Energy Conservation Award presented to CIT by the Irrigation Association, 1998.

Roy Williams Memorial Award presented to CIT for service to the industry by the American Society of Irrigation Consultants, 1996.

Edwin J. Hunter Industry Achievement Award for service to the industry presented to CIT by Hunter Industries, 1994.

PROFESSIONAL ACTIVITIES:

Co-Chair (2011), California Department of Water Resources, strategic planning caucus for New Water Technology: Objective 11.

Member (2010), A2 technical subcommittee to SBx7-7 Agriculture Stakeholder Committee, California Department of Water Resources.

Member, of the SWAT Executive Committee, Irrigation Association .

President (2005) of the nationally based Irrigation Association. The mission of the IA is to promote efficient irrigation technologies, products and services.

Vice-Chair (2005) for the AB2717 State Task Force on Landscape Irrigation.

President (2002) of the American Society of Agronomy, California Chapter.

INTERNATIONAL INVITATIONS:

Keynote Address at Irrigation Australia 2008. The Irrigation Association of Australia, Ltd., Melbourne Exhibition Centre.

Project Director for the establishment of the Zimbabwe Irrigation Technology Center, Harare, Zimbabwe. Completed contract for design, training, and facility development, December, 1996.

USA delegate to ISO / TC23 / SC18 Committee, Tel Aviv, Israel, October 1993. Appointed by the American National Standards Institute (ANSI), represented the USA position in developing international equipment standards.

USA delegate to ISO / TC23 / SC18 Committee, Aix En Provence, France, September 1991. Appointed by the American National Standards Institute (ANSI), represented the USA position in developing international equipment standards.

Visiting Scholar to the Dzhambul Institute for Irrigation, Land Reclamation and Civil Engineering (DICI), located in Dzhambul, Kazakhstan. Agreement made to develop joint irrigation demonstration and educational plots in Dzhambul region, May 1991.

Keynote Address to the Fourth International Micro-Irrigation Congress, Albury-Wadonga, Australia. Presentation on the
Role of an Independent Test Laboratory in Micro-Irrigation,
October, 1988.

BOOKS:

Green, S., K. Vang, and **D.F. Zoldoske**. 2011. Conservation and Environmental Protection. Chapter 16, pages *In* Irrigation 6th Edition, edited by L.E. Stetson and B. Mecham. Handbook published by the Irrigation Association (IA), Alexandria, VA, 1120 p.

Cassel S., F., D. Goorahoo, **D. Zoldoske,** and D. Adhikari. 2009. Mapping Soil Salinity using Ground-Based Electromagnetic Induction Technique". *In G.* Metternicht and A. Zinck (eds.), *Remote Sensing of Soil Salinization: Impact on Land Management*, Chapter 11, CRC Press, Boca Raton, FL, p. 199-233.

Barrett, J., B. Vinchesi, R. Dobson, P. Roche, and **D.F. Zoldoske**, authors. 2003. "Golf Course Irrigation: Environmental Design and Management Practices," John Wiley and Sons, Inc., Hoboken, New Jersey: 452.

Norum, E.N., J.C Oliphant, K.H. Solomon and **D.F. Zoldoske**. 1995. "Manual for Operation and Maintenance of Testing Equipment." FAO Project ZIM / 91/ 005, February 1995: 66.

Zoldoske, D.F., and M.Y. Miyasaki, editors. 1986. "Micro Irrigation: Methods and Materials Update," CATI Publication No. 861103, Center for Irrigation Technology, California State University, Fresno, CA: 295.

COMPUTER SOFTWARE:

Oliphant, J.C. and **D.F. Zoldoske**, 1989. "Sprinkler Profile And Coverage Evaluation (SPACE)", Software and Documentation, CATI Publication No. 890403, Center for Irrigation Technology, California

State University, Fresno, CA, 39 p.

SELECTED PUBLICATIONS:

Canessa, P., S. Green and **D. Zoldoske**. 2011. Agricultural Water Use in California: A 2011 Update. Staff Report, Center for Irrigation Technology, California State University, Fresno. 80 pp.

Cassel S., F. and **D. Zoldoske**. 2011. Estimating crop evapotranspiration and soil salinity from remote sensing imagery. Final report, California Agricultural Technology Institute. 22 pp.

Longley, K., B. Haddix, S. Greeen, and **D. Zolodske,** *Unincorporated and Underserved: Proposed Center for Disadvantaged Community Water Assistance*, Water Efficiency, The Journal for Water Efficiency, May-June 2011. http://www.waterefficiency.net/index.aspx

Zoldoske, D., S. Green, and S. Longville. 2009. "Capacity of CSU System for Assisting the Establishment of a Statewide Transparent Process for 20x2020 Goal". Presented to the Association of California Water Agencies (ACWA), California State University, p. 1-3, Apr. 24, 2009.

Burt, C., P. Canessa, L. Swankl, and **D. Zoldoske**. 2009. "Commentary: Widely Publicized Water-Conservation Report Drew Incorrect Conclusions". California Farm Bureau Federation, p. 1-2, Jan. 28, 2009.

St. Hilaire, R., M. Arnold, D. Wilkerson, D. Devitt, B. Hurd, B. Lesikar, V. Lohr, C. Martin, G. McDonald, R. Morros, D. Pittenger, D. Shaw, and **D. Zoldoske**. 2008. "Efficient Water Use in Residential Urban Landscapes", HortScience, Dec. 2008, 43: p. 2081-2092.

Zoldoske, D. 2008. "Irrigation Industry Challenges", Proceedings of the Desert Green XII conference, Las Vegas, NV, p. 1-5, Oct. 23, 2008.

Adhikari, D.D, **Zoldoske, D.F.** and Norum E. (2008). Featured in the AgAlert "Irrigation Technology: Smart water solution for state's farmers". AgAlert July 9th 2008.

Burt, C., P. Canessa, L. Swankl, and **D. Zoldoske**. 2008. "Agricultural Water Conservation and Efficiency in California-A Commentary", California State University, 13 pp., October 2008.

Huck, M.T. and **D.F. Zoldoske**. "Achieving High Efficiency in Water Application via Overhead Sprinkler Irrigation", Water Quality and Quantity Issues for Turfgrasses in Urban Landscapes, Council of Agricultural Science and Technology, Ames, Iowa, USA, 2008, pp. 223-242.

Zoldoske, D.F. 2007. "Sprinkler Systems Used for Frost Protection", Proceedings of the Workshop on Understanding and Preventing Freeze

Damage in Vineyards, Institute for Continental Climate Viticulture and Enology, Columbia, MO. Dec. 5 and 6, 2007, pp 79-88.

Zoldoske, D. An Overview of Smart Water Application Technologies™ (SWAT™) and Achieving High Water Use Efficiency. California Plant and Soil Conference, Sacramento, CA., 2007, pp. 111-119.

Cassel S., F. and **D. Zoldoske**. Assessing canal seepage and soil salinity using the electromagnetic remote sensing technology. *In* G. Lorenzini and C.A Brebbia (eds) Sustainable Irrigation management, Technologies and Policies. WIT Press. 2006, p. 55-63.

Goorahoo D., D. Adhikari, G Carstensen and **D. Zoldoske**. Impact of Aerated Subsurface Irrigation Water on the Growth and Yield of Crops. Proceedings of the Irrigation Association (IA) conference, Tampa, Florida, November 2004.

Goorahoo D., F. Cassel, M.Rothberg, D. Adhikari, **D. Zoldoske** and E Norum. Potential use of a New Forage Grass (*Pennisetum Sp.)* in Best Management Practices Involving Irrigation with Food Processing and Dairy Wastewaters. Proceedings of the Irrigation Association (IA) conference, Tampa, Florida, November 2004.

Cassel S., F., B. Taylor, and **D. Zoldoske**. Electromagnetic Sensing of Salinity and Boron for Predicting Variable Seeding Zones. Agronomy Abstracts, Soil and environmental Quality Division. Annual Meetings, American Society of Agronomy-Crop Society of Agronomy-Soil Science Society of America, Madison, WI., November 2004.

Sanliang Gu, Guoqiang Du, **David F. Zoldoske**, Abdul Hakim, Robert Cochran, Kenneth Fugalsang, and Greg Jorgensen. "Effect of irrigation amount on water relations, vegetative growth, yield and fruit composition of Sauvignon blanc grapevines in the San Joaquin Valley of California, USA." Journal of Horticultural Science and Biotechnology (2004) 79 (1) 26-33.

Zoldoske, David F., (technical advisor). "Wastewater Subsurface Drip Distribution, Peer-Reviewed Guidelines for Design, Operation, and Maintenance." Tennessee Valley Authority/Electric Power Research Institute, Report #1007406, 2004.

Cassel S., F., **D. Zoldoske,** E. Norum, and T. Jacobsen. "Detecting Canal Seepage using the Electromagnetic Induction Technique." Proceedings, Technical Conference of the Irrigation Association, San Diego, CA., November 2003.

Cassel S., F**., D. Zoldoske**, and M. Spiess. "Assessing Spatial and Temporal Variability of Soil Salinity on Farms Implementing Integrated Drainage Management Practices." Final Report. California Department of Water

Resources, CALFED Agricultural Water Use Efficiency Program, Sacramento, CA: 35.

Cassel S., F., B. Taylor, B. Roberts, and **D. Zoldoske**. "Precision Farming Applications in Cotton Systems of California." Final Report, Cotton Incorporated, Cary, NC: 19.

Zoldoske, David F., "A Simple Step Toward Savings", Golf Course Management, Lawrence, KS 66049, January 2004, pp. 209-213.

Zoldoske, David F., "Improving Golf Course Irrigation Uniformity: A California Case Study". CATI Publication #030901, September 2003, 17 pp.

Zoldoske, David F., "Improving Golf Course Irrigation Uniformity: A California Case Study". On the Road-Quarterly Bulletin,Vol. 3, No. 2, Northern California Golf Association, p. 2.

Goorahoo D., G. Carstensen and **D. Zoldoske.** 2003. Evaluation of the addition of surfactant to irrigation water for improving irrigation on commercial turf systems. CATI/ARI Final Report: Surfactant #01-2-012-11.

Goorahoo D., G. Carstensen and **D. Zoldoske**, S Kostka, K. Mauser and M. Franklin 2002. "Addition of Surfactants to Improve Irrigation Efficiency in Turf Systems." Proceedings, Technical Conference of the Irrigation Association, October, 2002.

Zoldoske, D.F. "Choose the Right Drip for the Your Vineyard," Western Fruit Grower, March 2002, Vol. 122, No. 3, p16M.

Goorahoo, D., G. Carstensen, **D.F. Zoldoske**, E. Norum, and A. Mazzei. "Using Air in Sub-Surface Drip Irrigation (SDI) to Increase Yields in Bell Peppers," Proceedings, California Chapter of American Society of Agronomy, Energy and Agriculture: Now and in the Future 2002 conference, Fresno, CA., February 5th and 6th, 2002: 10-15.

Zoldoske, D.F. 2001. "The Water/Energy/Environmental Matrix." California Grower magazine, Vol. 25, No. 11, December 2001: 22.

Zoldoske, D.F. 2001. "Water, Energy and Education: Where Professionalism Does Make a Difference." Full Coverage Irrigation, The Newsletter of the American Society of Irrigation Consultants, Winter/Spring, 2001: 6-8.

Zoldoske, D.F. 2001. "How Will the Changing Drip/Micro Marketplace Affect the Grower?" California Grower magazine, Vol. 24, No. 5, May 2001: 16.

Zoldoske, D.F. 2001. "California at the Crossroads." California Grower magazine, Vol. 25, No. 4, April 2001: 20.

Zoldoske, D.F. 2000. "Subsurface Drip Irrigation: The Future of Irrigation Is Underground." The Western Chestnut, Published by the Western Chestnut Grower Association, Inc., Vol. 3, No. 1, Winter 2000: 6-7.

Zoldoske, D.F. 2000. "The Water Institute has its Beginning." California Grower magazine, Vol. 24, No. 10, November 2000:18, 20.

Zoldoske, D.F. 2000. "Whiskey is for Drinking and Water is for Fighting!" California Grower magazine, Vol. 24, No. 8, September 2000: 22.

Zoldoske, D.F. 2000. "Low Volume Irrigation: Design and Installation Guide." Technical editor, produced by the City of Albuquerque, New Mexico, April 2000: 24.

Zoldoske, D.F. 2000. "Water, Technology, and Our Future." California Grower magazine, Vol. 24, No. 3, March 2000: 26.

Gu, S., **D.F. Zoldoske**, S. Graves, and G.S. Jorgensen. 2000. "Effect of Partial Rootzone Drying on Vineyard Water Use, Vine Water Relation, Yield Components, and Fruit Composition in Field-Grown Mature Sauvignon blanc Grapevines-A Preliminary Evaluation in California." Proceedings of the 2000 California Plant and Soil Conference, January 19th and 20th, Stockton, CA: 75-80.

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EDUCATION

PhD Agriculture-Plant Nutrition, 06/87, Hohenheim University, Stuttgart, West Germany (FRG)
MS Agriculture, 01/84, California Polytechnical State University, San Luis Obispo, CA
BS Crop Science, German Proficiency Certificate, 06/82, California Polytechnical State University, San Luis Obispo, CA; Plant Biology (Diploma level), 09/79-061/81, Tubingen University, Tübingen, FRG
BA German, Special Emphasis: Speech and Communication, 06/79, California State University, Arcata, CA; German Certificate, 08/77, Middlebury College; VT Spanish Certificate, 02/90, Cuernavaca Language Institute, Cuernavaca, Mexico; International Study Abroad Program in Germany; 09/79-06/81, and 06/82-05/83 Tuebingen and Hohenheim Universities, West Germany
Adjunct Professor CSU Fresno, Fresno CA (granted 2000-present)
Honorary Visiting Professor Anhui University, Hefei, China (awarded 10/10-present)

EXPERIENCE

Plant/Soil Scientist: United States Department of Agriculture, Fresno, CA. Analyzes for Se, B and other trace elements in plants, soils, and waters; identifies alternative crops for contaminated soils; uses phytoremediation to remove toxic constituents from contaminated soils and waters; produces biofuel and biofortified food and feed products; supervisor of inorganic chemical laboratory; supervise eight graduate students and two postdocs; has extensive public-relations nationally and internationally as public speaker and guest lecturer and interacts intensively with European, Asian, and South American colleagues. 01/88-present

Guest Lecturer on Bioremediation of Contaminated Soils: Guest Professor at Institute of Ecology, Xalapa, Mexico (daily) 08/10-08/10

Guest Lecturer on Contaminated Environment: Guest Professor-University of Science and Technology, Hefei, China (daily) 06/10-07/10

Guest Lecturer on Salinity and Trace Elements: Guest Professor-Swiss Federal Institute of Technology (ETH), Zuerich, Switzerland (weekly) 04/09-09/09, 06/14-09/14

Scientific Consultant for CH2MHill and Ecolitree Companies 10/98-present

Guest Lecturer on Research Writing: California State University Fresno, Fresno, CA. (4hrs) 07/98

Lecturer of Plant Nutrition: CSU Fresno, Fresno, CA. (weekly) 01/14-06/14, 01/93-07/93 01/96-07/96

Lecturer of Environmental and Sustainable Agriculture Studies: University of California (UC) Santa Cruz, Santa Cruz, CA. (weekly) 10/90-01/91

NATIONAL AND INTERNATIONAL RECOGNITION

Awarded OECD to fund 6-month sabbatical in Zurich, Switzerland	12/14
Awarded 2nd best Environmental Technology publication for *J. Environmental Science and Technology* (*46,3601-3602)*	03/12
Selected scientific publication selected as "Science Brief" for Advanced Light Source Web pages: http://www-als.lbl.gov/index/php./science-highlights/scienc-briefs/645 on Selenium-accumulation-distribution-and-speciation-in-spineless-prickly pear	03/12
Received recognition as Best Distinction ARI Grant Proposal for CSU California	09/10
Awarded OECD and funded 6-month sabbatical in Zurich, Switzerland	01/09
Produced PBS-KQED Documentary television Film "Green Energy" on incumbent's research	06/06
Awarded OECD and funded 3-month sabbatical in Zurich, Switzerland	12/03
Produced PBS Documentary television Film "Green Means" about incumbent's research on natural cleanup of soil and water	04/00
Awarded Best research publication for *J. Soil and Water Conservation*	01/98
Awarded OECD and funded 4-week sabbatical in Bern, Switzerland	09/96
Produced PBS Documentary television Film "Phytoremediation" on incumbent	11/95
Awarded USDA Early Career Scientist of the Year	01/92
Awarded National Science Foundation Fellowship for PhD	06/83- 06/86
Awarded Fulbright Scholarship for Germany	06/82- 10/83

AWARDS

Outstanding Performance Merit Award, USDA	01/09- 01/10
Superior Performance Merit Award, USDA	01/02-01/14
Certificate of Appreciation for Student Employment	05/99
Pacific West Area Award for Equal Employment Opportunity (EEO) Activities, USDA	06/95
Outstanding Performance Award for EEO Activities, USDA	09/94, 02/94 & 10/93
Best BS Thesis in Agriculture, CSU San Luis Obispo	06/82
Leopold Wrasse Scholarship, CSU San Luis Obispo	10/81
DAAD (German Exchange Service) Scholarship, FRG	10/79

GRANTS (Received as principal investigator)

Table Grape Commission for $19,000 for nutritional quality in berries	01/13
USDA-Dept. of Navy for $400,000 for studying biofuel production	02/12

CATI Grant for $ 185,000 for performing speciation in Opuntia cactus plants	01/12
CATI Grant for $160,000 for producing Opuntia fruit products	04/09
DWR Grant for $ 75,000 for growing Opuntia in contaminated soils	07/08
CATI Grant for $105,000 for animal feed trial with Se enriched products	09/06
DWR Grant of $50,000 for water ruse and biofuel production	06/06
CATI Grant for $160,000 for biofuel production and emission evaluation	01/06
Edenspace Systems Grant for $20,000 for evaluating water reuse on canola	06/03
CATI Grant of $75,000 for evaluating organic broccoli and Se accumulation	06/02
CATI Grant of $75,000 for evaluating canola and biofuel production	06/02
DWR Grant of $65,000 for evaluating drainage water and biofuel production	10/02
CSREES Grant of $75,000 for evaluating broccoli nutrient and trace element status in central California	06/00
CATI Grant of $30,000 for evaluating water uptake in vegetables	09/00
CATI Grant of $9,000 for evaluating biosolids and apricot production	04/00
CSU Fresno Grant of $63,000 for Minority Science Scholars Program	04/00
CATI Grant of $150,000 for evaluating cleanup of sediment with plants	04/00
UC Salinity Task Force Grant of $20,000 for biotransfer of Se to insects	06/99
Colorado State University Grant of $6000 for evaluating salt tolerance of crops	01/98
Egyptian-USA Grant of $100,000 for evaluating faba beans and water usage	06/97
Alcoa Grant of $43000 for evaluating chloride accumulation in salt tolerant plants	08/96
Borax Grant of $7000 for evaluating boron tolerance in plants	08/96
Ecolitree Grant of $14,000 for evaluating Poplar trees irrigated with saline and B water	08/95
OICD Award of $7000 for evaluating boron-contaminated soils in Chile (2 weeks)	03/95
CSU Fresno Grant of $40,000 for Science Scholars Program for minority college students	08/94
UC Salinity Task Force Grant of $20,000 for bioremediation of Se	06/94
USDA funding of $45,000 for Post-doctoral position	01/94
PIMA Grant of $4500 for monitoring trace elements in biosolids applied to soils	01/94

GRANTS (Participating as co-investigator)

CEC with Mendota Bioenergy LLC for $5,000,000 for biofuel/ethanol	03/13
CATI Grant for $ 227,000 for studying effects of selenium on Talapia fish	01/12
USDA-CREES Grant for $ 1,200,000 for studying effects of salt and water on grape quality	01/11
CATI Grant for $245,000 for studying poplar tree genomics for salt tolerance	01/10
USDA-CREES Grant for $1,700,000 for studying effects of selenium on biological Nutrition	06/04

PATENTS (as lead investigator)

US Plant Patient Serial No. 13/506,026 Seleno Green Opuntia PP24053	11/13
US Plant Patient Serial No. 13/506,028 Seleno Orange Opuntia PP24039	11/13
US Plant Patient Serial No. 13/506,029 Seleno Purple Opuntia PP24072	11/13
US Plant Patient Serial No. 13/506,030 Seleno Red Opuntia PP24052	11/13

US Plant Patient Serial No. 13/694,691 RRR Yellow Poplar (approved 2013)

CRADA

Developed a CRADA between Red Rock Ranch (RRR) and USDA-ARS for co-developing new bio-based products from poor quality soils and waters at RRR (1/13).

INTERNATIONAL COOPERATION (presently in 2014)

President of the International Selenium Research Society
University of Science and Technology, Professor Xiebin Yin, Suzhou, China
University of Zurich, Professor Rainer Schulin, Zurich, Switzerland
University of Zurich, Dr. Pierre Wollenweider, Zurich, Switzerland
University of Antofagasta, Professor Luis Caceras, Antofagasta, Chile
University of Punjab, Professor Karaj Dhillon, Punjab, India
Anhui University, Dr. Li Miao, Hefei, China

PUBLICATIONS

1. **Bañuelos, G.S.**, G.P. Offerman, and E.C. Seim. High relative humidity promotes blossom-end rot on growing tomato fruit. *HortScience*, 20(5):894-895. 1985.
2. **Bañuelos, G.S.** The relationship between the IAA transport and the acropetal movement of calcium into tomato fruits. Ph.D. Dissertation, University of Hohenheim, Germany. 1986.
3. **Bañuelos, G.S.** and F. Bangerth. Interrelationship between IAA- and Ca-transport in respect to Ca- nutrition of fruits. *Acta Horticulturae*, 179: 817-819. 1986.
4. **Bañuelos, G.S.**, F. Bangerth and H. Marschner. Relationship between polar basipetal auxin transport and acropetal Ca2+ transport into tomato fruits. *Physiologia Plantarum*, 71:321-327. 1987.
5. **Bañuelos, G.S.**, F. Bangerth and H. Marschner. Basipetal auxin transport in lettuce and its possible involvement in acropetal calcium transport and incidence of tipburn. *Journal of Plant Nutrition*, 11(5):525-533. 1988.
6. **Bañuelos, G.S.** Using Plants to lower selenium concentration in soil. Proceedings of Tenth Annual Central California Research Symposium, Plant and Soil Soc. of Calif., Fresno, CA, May, 10:2-10. 1989.
7. **Bañuelos, G.S.**, and D.W. Meek. Selenium accumulation in selected vegetables. *Journal of Plant Nutrition*, 12(10):1255-1272. 1989.
8. **Bañuelos, G.S.**, and G. Schrale. Plants that remove selenium from soils. California Agriculture, May/June 1989. pp. 19-20. 1989.
9. **Bañuelos, G.S.** and D.W. Meek. Accumulation of selenium in plants grown on selenium-treated soil. *Journal of Environmental Quality*, 19(4):772-777. 1990.
10. **Bañuelos, G.S.** and T. Pflaum. Determining selenium in plant tissue with optimal digestion conditions. *Communications in Soil Science and Plant Analysis*, 21(13-16): 1717-1726. 1990.
11. **Bañuelos, G.S.**, D.W. Meek, and G.J. Hoffman. The influence of selenium, salinity,

and boron on selenium uptake in wild mustard. *Plant and Soil*, 127:201-206. 1990.

12. **Bañuelos, G.S.** and L.H. Aung. The effects of sodium 2.3-dichloroisobutyrate on growth of wild mustard and the uptake of selenium. *International Journal of Experimental Botany*, 52(2):141-150. 1991.
13. **Bañuelos, G.S.**, R. Mead, and S. Akohoue. Adding selenium-enriched plant tissue to soil causes the accumulation of selenium in alfalfa. *Journal of Plant Nutrition*, 14(7): 701-713. 1991.
14. **Bañuelos, G.S.**, G. Cardon, T. Pflaum, and S. Akohoue. Comparison of dry ashing and wet acid digestion on the determination of boron in plant tissue. *Communications in Soil Science and Plant Analysis*, 23(17-20):2383-2397. 1992.
15. **Bañuelos, G.S.**, G.E. Cardon, B. Mackey, J. Ben-Asher, L. Wu, and P. Beuselinck. Boron and selenium removal in boron-laden soil by Birdsfoot Trefoil. In: P.R. Beuselink (ed.) Lotus Newsletter 1992, 23:32-35, USDA-ARS, Columbia, MO. (popular press) 1992.
16. **Bañuelos, G.S.**, R. Mead, D.W. Meek, and C.J. Phene. Relations between phosphorus in drip irrigation water and selenium uptake by wild mustard. *Journal of Environmental Science and Health*, A27 (1):283-297. 1992.
17. **Bañuelos, G.S.**, R. Mead, L. Wu, P. Beuselinck, and S. Akohoue. Differential selenium accumulation among forage plant species grown in soils amended with selenium-enriched plant tissue. *Journal of Soil and Water Conservation*, 47(4):338-342. 1992.
18. **Bañuelos, G.S.**, S. Tebbets, R. Perry, J.E. Duffus, and P. Vail. The potential of non-native selenium accumulating mustard plants as host for beet leafhopper and beet curly top virus. *Southwestern Entomologist Scientific Note*, 17(1):73-75. 1992.
19. Speiser, D.M., S.L. Abrahamson, **G.S. Bañuelos**, D.W. Ow. Brassica juncea produces a phytochelatin-cadmium-sulfide complex. *Plant Physiology*, 99 (3):817-821. 1992.
20. **Bañuelos, G.S.** Bio-remediation of seleniferous soils in Central California with selenium accumulator crops. Proceedings of "Food Systems and the Environment", at Trilateral Faculty Exchange Seminar, Between Korea and CSU Fresno, Fresno, CA, August 10-11, pp. 219-230. 1993.
21. **Bañuelos, G.S.**, D. Dyer, R. Ahmad, S. Ismail, R.N. Raut, J.C. Dagar. In search of Brassica germplasm in saline semi-arid and arid regions of India and Pakistan for reclamation of selenium-laden soils in the U.S. *Journal of Soil and Water Conservation*, 48(6):530-534. 1993.
22. **Bañuelos, G.S.**, G.E. Cardon, B. Mackey, J. Ben-Asher, L. Wu, and P. Beuselinck. Boron and selenium removal in boron-laden soil by 4 Sprinkler Irrigated Plant Species. *Journal of Environmental Quality*, 22(4): 786-792. 1993.
23. **Bañuelos, G.S.**, G.E. Cardon, C.J. Phene, L. Wu, S. Akohoue and S. Zambrzuski. Soil boron and selenium removal by three plant species. *Plant and Soil*, 148:253-263. 1993.
24. **Bañuelos, G.S.**, L. Wu, S. Akohoue, S. Zambrzuski, and R. Mead. Trace element composition of different plant species used for remediation of boron-laden soils. In: N.J. Barrow (ed.), Plant Nutrition - from Genetic Engineering to Field Practice. Kluwer Academic Publishers, Dordrecht/Boston/Lancaster, pp. 425-428. 1993.
25. **Bañuelos, G.S.**, R.R. Mead, and G.J. Hoffman. Accumulation of selenium in wild mustard irrigated with agricultural effluent. *Agriculture, Ecosystems and Environment*, 43:119-126. 1993.

26. **Bañuelos, G.S.**, S. Akohoue, S. Zambrzuski, S. Downey, R. Mead, M. Bhangoo. Boron and selenium removal in boron-laden soils by kenaf. Proceedings of 1993 International Kenaf Conference, Fresno, CA, March 3-5, pp. 84-91. 1993.
27. **Bañuelos, G.S.**, P. Bueselinck. Remediation of selenium and boron contaminated soil with Lotus corniculatus L. Proceedings of the First International Lotus Symposium, St. Louis, MO, March 22-24, pp. 167-171. 1994.
28. **Bañuelos, G.S.**, S. Akohoue. Comparison of microwave digestion with block digestion for selenium and boron analysis in plant tissues. *Communications in Soil Science and Plant Analysis*, 25(9 & 10):1655-1670. 1994.
29. **Bañuelos, G.S.**, S. Zambrzuski, S. Akohoue, S. Downey. Bioremediation of Seleniferous Soils with Selected Plants. In 15th World Congress of Soil Science, July 10-16, 1994, Acapulco, Mexico. Commission III. Poster Sessions. 4b: 224-225. 1994
30. Watson, M.C., **G.S. Bañuelos**, J.W. O'Leary, J.J. Riley. Trace element composition of Atriplex grown with saline drainage water. *Agriculture Ecosystems & Environment*, 48(2):157-162. 1994.
31. **Bañuelos, G.S.** Managing high levels of B and Se with trace element accumulator crops. *Journal of Environmental Science and Health*, A31 (5):1179-1196. 1995.
32. **Bañuelos, G.S.**, B. Mackey, L. Wu, S. Zambrzuski, and S. Akohoue. Bioextraction of soil boron by tall fescue. *Journal of Ecotoxicology and Environmental Safety*, 31:110-116. 1995.
33. **Bañuelos, G.S.**, L.H. Aung, S. Akohoue, D. Fouse. Effects of sodium 2,3-Dichloroisbutyrate (DCB) on dry matter and sugar distribution in the organs of Brassica juncea L. Czern. *International Journal of Experimental Botany*, 57(2):159-165. 1995.
34. **Bañuelos, G.S.**, N. Terry, A.M. Zayed, L.L. Wu. Managing high soil selenium with phytoremediation, pp. 394-405 In: G.E. Schuman and G.F. Vance (eds.), Decades later: A time for reassessment, Volume 1, Selenium, Mining, Reclamation and Environmental Impacts. American Society for Surface Mining and Reclamation, Gillette, WY, June 5-8. 1995
35. Wu, L., J. Chen, K.K. Tanji, **G.S. Bañuelos**. Distribution and biomagnification of selenium in restored upland grassland contaminated by selenium from agricultural drainwater. *Environmental Toxicology and Chemistry*, 14(4):733-742. 1995.
36. **Bañuelos, G.S.** Managing high levels of B and Se with trace element accumulator crops. *Journal of Environmental Science and Health*, 31:1179-1196. 1996.
37. **Bañuelos, G.S.**, A. Zayed, N. Terry, S. Akohoue, and S. Zambrzuski. Accumulation of selenium by different plant species grown under increasing sodium and calcium chloride salinity. *Plant and Soil*, 183:49-59. 1996.
38. **Bañuelos, G.S.**, B. Mackey, C. Cook, S. Akohoue, S. Zambrzuski, and P. Samra. Response of cotton and kenaf to boron-laden water and soil. *Crop Science*, 36:158-164. 1996.
39. Bost, G.A., **G.S. Bañuelos**, S. Downey, & J.W. Sy, Jr. Germination and establishment of Hibiscus species exposed to saline irrigation water and soils contaminated with trace elements B & Se. Proceedings of the 1996 International Kenaf Conference in Albuquerque, NM. March 21-24, pp. 191-200. 1996.
40. **Bañuelos, G.S.**. Phytoremediation of Se applied to soils in Municipal Sewage Sludge. 1st International Conference-Contaminants and the Soil Environment Australia-Pacific Extended Abstract Adelaide, Australia Feb. 18-23. pp 311-312. 1996.

41. Van Mantgem, P.J., L. Wu, and **G.S. Bañuelos**. Bioextraction of selenium by forage and selected field legume species in selenium-laden soils under minimal field management conditions. *Journal of Ecotoxicology and Environmental Safety*, 34:228-238. 1996.
42. Abegaz, M., W. Goessler, **G.S. Bañuelos**, and K.J. Irgolic. Determination of selenium compounds in biological samples with high pressure liquid chromatography using ICP-MS as selenium specific detector. Proceedings of the International Conference on Plasma Spectro-Chemistry. Jan. 12-17, 1997. Gent, Belgium, p. 1-5. 1997.
43. **Bañuelos, G.S.** and H.A. Ajwa. Evaluation of the growth of Atriplex in B-laden soils covered with varied depths of cover soil. 35 pp. Submitted report to Condor Engineering Company, CA. 1997.
44. **Bañuelos, G.S.** and P. Beuselinck.Evaluating species in saline conditions. submitted report to Colorado State Cooperative Extension, Rocky Ford, CO 1-16. 1997.
45. **Bañuelos, G.S.**, H. Ajwa, B. Mackey, L. Wu, C. Cook, S. Akohoue, and S. Zambrzuski. Evaluation of different plant species used for phytoremediation of high soil selenium. *Journal of Environmental Quality*, 26:639-646. 1997.
46. **Bañuelos, G.S.**, H. Ajwa, S. Zambrzuski, and S. Downey. Phytoremediation of Selenium-Laden Field Soils. Symposium: Phytoremediation of Trace element-contaminated soil and water. 1997.
47. **Bañuelos, G.S.**, H.A. Ajwa, L. Wu, Xun Guo, S. Akohoue, and S. Zambrzuski. Selenium induced growth reduction in Brassica land races considered for phytoremediation. *Journal of Ecotoxicology and Environmental Safety*, 36:282-287. 1997.
48. **Bañuelos, G.S.**, H.A. Ajwa, N. Terry, and A. Zayed. Phytoremediation of selenium laden soils - a new technology! *Journal of Soil & Water Conservation*, 52: 426-430. 1997.
49. Cook, C.G. and **G.S. Bañuelos**. Inheritance of a white flower mutant in kenaf. *Journal of Heredity*, 88(6):559-560. 1997.
50. Jayaweera, G., T. Tokunaga, W.T. Frankenberger, N. Terry, **G.S. Bañuelos**. Selenium remediation in soils, sediments and waters. Proceedings Chapter, AAAS Symposium, Toxic Trace Elements, Sustainability in Agroecosystems, San Francisco, CA, June 19-23. 1997.
51. L. Wu, X. Guo, and **G.S. Bañuelos**. Accumulation of seleno-amino acids in legume and grass plant species grown in selenium laden soils. *Environmental Toxicology and Chemistry*, 16:491-497. 1997.
52. Nable, R.O., **G.S. Bañuelos**, J.G. Paull. Boron Toxicity. In: B. Dell, P. Brown and P. Bell (eds.) Boron in Soils and Plants: Reviews. Kluwer Acad. Pub. *Plant and Soil*, 2193: 181-198. 1997.
53. Wondmu, T., Goessler, W., Abegaz, M., Bañuelos, G., Irgolic, K. Retention behavior of inorganic and organic selenium compounds on a polymer-based cation exchange column. *Pediatric and Perinatal Drug Therapy*. 1(2): 327-352. 1997.
54. Ajwa, H.A., **G.S. Bañuelos**, H.F. Mayland. Selenium uptake by plants from soils amended with inorganic and organic materials. *Journal of Environmental Quality*, 27:1218-1227. 1998.
55. **Bañuelos, G.S.** Evaluation of several plant species for salt tolerance under waterlogged and well-drained conditions, 67 pp., submitted report to Aluminum Company of

America, Lebanon, PA. 1998.

56. **Bañuelos, G.S.** Phytoremediation of Se-laden soils. EPA Technology Trends May pp. 5-6. 1998.
57. **Bañuelos, G.S.**, H.A. Ajwa, B. Makey, L. Wu, C. Cook, S. Akohoue, S. Zambruzuski. Evaluation of different plant species used for Phytoremediation of high soil selenium. *Journal of Environmental Quality*. 26:639-646. 1998.
58. **Bañuelos, G.S.**, H.A. Ajwa, L. Caceres, and D. Dyer. Diferencias de acumulacion y tolerancia a altas concentraciones de boro de especies agricolas entre el norte de Chile y California, Estado Unidos Proceedings de Congress Internacional de Agricultura Para Zonas Aridas. 8pp. 1998.
59. **Bañuelos, G.S.**, H.A. Ajwa, L. Wu, and S. Zambrzuski. Challenges with phytoremediation of selenium laden soil. Soil and Groundwater Cleanup, Feb/March pp. 6-10. 1998. (technical trade publication)
60. **Bañuelos, G.S.**, H.A. Ajwa, L. Wu, and S. Zambrzuski. Selenium accumulation by Brassica napus grown in Se-laden soil from different depths of Kesterson Reservoir. *Journal of Contaminated Soil*, 71:481-496. 1998.
61. Wondimu, T., W. Goessler, M. Abegaz, **G.S. Bañuelos**, and K. Irgolic. Retention behavior of inorganic and organic selenium compounds on a polymer-based cation exchange column. *Journal of Chromatography, Phosphorus, Sulphur, and Silico*. 136, 137, 138:327-352. 1998.
62. **Bañuelos, G.S.** and H.A. Ajwa. Trace elements in soils and plants: an overview. *Journal of Environmental Science and Health*, A34:951-975. 1999.
63. **Bañuelos, G.S.**, H.A. Ajwa, L. Caceres, and D. Dyer. Germination Responses and boron accumulation in germplasm from Chile and the United States grown with boron-enriched water. *Journal of Ecotoxicology and Environmental Safety*, 43:62-67. 1999.
64. **Bañuelos, G.S.**, J.S. Tebbets, J. Johnson, P.V. Vail and B. Mackey. Insect Diversity in Phytoremediation and Bioaccumulation of Se. *International Journal of Phytoremediation*, 1(4):311-326. 1999.
65. **Bañuelos, G.S.**, M.C. Shannon, H.A. Ajwa. J.H. Droper, J. Jordahl, and L. Licht. Phytoextraction and accumulation of B and Se by poplar (populus) hybrid clones. *International Journal of Phytoremediation*, 1:81-96. 1999.
66. Shannon, M.C., **G.S. Bañuelos**, J.H. Draper, H.A. Ajwa, J. Jordahl, and L. Licht. Tolerance of hybrid poplar (populus) trees irrigated with varied levels of salt, selenium, and boron. International *Journal of Phytoremediation*, 1:273-288. 1999.
67. **Bañuelos, G.S.** Phytoremediation. In: Licker et al. (Eds.) 2001 Yearbook of Science and Technology. McGraw-Hill, NY, NY. pp. 305-306. 2000.
68. **Bañuelos, G.S.** Factors Influencing Field Phytoremediation of Selenium-Laden soils. In: N. Terry and **G.S. Bañuelos** (eds.) Phytoremediation of Contaminated Soils and Waters. CRC Press, Boca Raton, Fl. pp .41-59. 2000.
69. **Bañuelos, G.S.** Salt-tolerant plants may provide means for reducing soil selenium. California Agricultural Research Initiative Technical Research Report. #00-2-004. 5pp. 2000.
70. **Bañuelos, G.S.** and H. Mayland. Adsorption and distribution of selenium in animals consuming canola grown for selenium phytoremediation. *Journal of Ecotoxicology and Environmental Safety*, 46:322-328. 2000.
71. **Bañuelos, G.S.** and S. Zambrzuski. Phytoextraction of selenium from soils irrigated

with selenium-laden effluent. *Plant and Soil*, 224:251-258. 2000.

72. Terry, N. and **G.S. Bañuelos**. Phytoremediation of Contaminated Soil and Water. In: N. Terry and **G.S. Bañuelos** (eds.) CRC Press LLC, Boca Raton, Fl. 389pp. 2000.
73. Trumble, J., M. Shannon, and **G.S. Bañuelos**. Evaluation of Atriplex as a potential new crop for integrated production systems in the San Joaquin Valley. UC Center for Water Resources. UC Salinity/Drainage Task Force Report, 228-244. 2000.
74. Wu. L., **G.S. Bañuelos**, and X. Guo. Changes of soil and plant tissue selenium status in an upland grassland transformed from a wetland habitat ten years after contaminated by selenium rich agricultural drainage sediment. *Journal of Ecotoxicology and Environment Safety*, 47:201-209. 2000.
75. **Bañuelos, G.S.** The green technology of selenium phytoremediation. *Journal of Biofactors*, 14:255-260. 2001.
76. **Bañuelos, G.S.** and S. Sharmasarkar. Vegetative approach to manage poor water quality in central California. In: Horst et al. (eds.) Plant Nutrition-Food Security and Sustainability of Agro-ecosystems through Basic and Applied Research. Kluwer Academic Publishers, Dordrecht, The Netherlands, pp. 382-384. 2001.
77. **Bañuelos, G.S.** Irrigation of Broccoli and canola with boron and selenium-laden effluent. *Journal of Environmental Quality*, 31:1802-1808. 2002.
78. **Bañuelos, G.S.** Orchard Study of long-term biosolids application shows no significant negative effects on apricot fruit. California State University, Fresno, CATI-ARI Publication #00-1-002-1B. 2002.
79. **Bañuelos, G.S.** Irrigation of Broccoli and Canola with Boron and Selenium-laden Effluent. *Journal of Environmental Quality*, 31:1802-1808. 2002.
80. **Bañuelos, G.S.**, A. Zayed, and B. Mackey. Growth of faba bean (Vicia faba L.) irrigated with saline drainage water. Journal of Plant Nutrition, 25:1101-1114. 2002.
81. **Bañuelos, G.S.**, and S. Pasakdee. Effect of organic fertilizers on vegetable production. Biocycle Aug. 63. 2002.
82. **Bañuelos, G.S.**, D.B. Vickerman, J.T. Trumble, M.C Shannon, C.D. Davis, and J.W. Finley. Biotransfer possibilities of selenium from plants used in phytoremediation. *International Journal of Phytoremediation*, 4:315-331. 2002.
83. **Bañuelos, G.S.**, D.R. Bryla, and C. Cook. Vegetative production of kenaf and canola under irrigation in Central California. *Journal of Oil Crops, Products and Utilization* 15:237-245. 2002.
84. **Bañuelos, G.S.**, Z. Q. Lin, L. Wu, and N. Terry. Phytoremediation of selenium-contaminated soils and waters: fundamentals and future prospects. *Reviews on Environmental Health*, 17(4):291-306. 2002.
85. Vickerman, D.B., M.C. Shannon, **G.S. Bañuelos**, C.M. Grieve, and J.T. Trumble. Evaluation of Atriplex lines for phytoremediation of selenium contaminated substrates: selenium accumulation, salt tolerance and suitability for a key agricultural insect pest. *Journal of Environmental Pollution*, 120:463-473. 2002.
86. **Bañuelos, G.S.** and P. R. Beuselinck. Growth of three forage species in saline conditions. *Journal of Arid Land Research and Management*, 17:13-22. 2003.
87. **Bañuelos, G.S.**, S. Pasakdee, and J.W. Finley. Growth response and selenium, boron distribution in broccoli varieties irrigated with poor quality water. *Journal of Plant Nutrition*, 26:2537-2549. 2003.
88. **Bañuelos, G.S.**, S. Sharmasarkar, D. Cone, and G. Stuhr. Vegetative approach for

improving the quality of water produced from soils in the Westside of central California. *Plant and Soil*, 249:229-236. 2003.

89. Bryla, D.R., **G.S. Bañuelos**, and J. P. Mitchell. Water requirements of subsurface drip Irrigated faba bean in California. *Irrigation Science*, 22:31-37. 2003.
90. Steiner, J.J. and **G.S. Bañuelos**. Registration of ARS-NLT-Salt and ARS. NLT-Salt/B saline tolerant narrow leaf-trefoil germplasm. Reg. # C03R-005 GP. *Crop Science*, 43:1888-1889. 2003.
91. Wu, L., X. Guo, and **G.S. Bañuelos**. Selenium and sulfur accumulation and soil selenium dissipation in planting of four herbaceous plant species in soil contaminated with drainage sediment rich in both selenium and sulfur. *International Journal of Phytoremediation*, 5:25-40. 2003.
92. **Bañuelos, G.S.** Potential use of plants for selenium reclamation. In: R.I. Barnhisel. (ed.) 2004 National Meeting of the American Society of Mining and Reclamation and 25th West Virginia Surface Mine Drainage Task Force. Morgantown, W. Virginia. Published by American Society of Mining and Reclamation, Lexington, KY. Pp. 105-110. 2004
93. **Bañuelos, G.S.**, S. Sharmasarkar, and S. Pasakdee. Utilization of biosolids as a fertilizer for canola. Journal of Compost Science and Utilization, 12:61-68. 2004.
94. **Bañuelos, G.S.** and Z.Q. Lin. Phytoremediation management of Se-laden drainage sediments in the San Luis Drain: a greenhouse feasibility study. *Ecotoxicology and Environmental Safety*, 62:309-316. 2005.
95. **Bañuelos, G.S.**, and J.A. Ayars. Application of field phytoremediation under high saline and boron conditions. In: C.J. Li et al. (eds.) Plant nutrition for food security, human health and Environmental protection. Tsinghua University Press, Beijing China. 1-6. 2005.
96. **Bañuelos, G.S.**, N. Terry, D. LeDuc, E.A.H. Pilon-Smits, and B. Mackey. Field Trial of Transgenic Indian mustard plants show enhanced phytoremediation of selenium-contaminated sediments. *Environmental Science Technology*, 39:1771-1777. 2005.
97. **Bañuelos, G.S.**, Z.Q. Lin, I. Arroyo, and N. Terry. Selenium volatilization in vegetated agricultural drainage sediment from the San Luis Drain, Central California. *Chemosphere*, 60:1203-1213. 2005.
98. Robbins, R.J., A.S. Keck, **G.S. Bañuelos**, and J.W. Finley. Cultivation conditions and Selenium fertilization alter the phenolic profile, glucosinolate, and sulforaphane content of broccoli. *Journal of Medicinal Food*, 8(2):204-14. 2005.
99. **Bañuelos, G.S.** Multi-faceted considerations for sustaining field phytoremediation. *Journal of Forest, Snow and Landscape Research*, 80:235-245. 2006.
100. **Bañuelos, G.S.** Phyto-products may be essential for sustainability and implementation of phytoremediation. *Journal of Environmental Pollution*, 144:19-23. 2006.
101. **Bañuelos, G.S.** and Z.Q. Lin. Reuse of agricultural drainage water in central California: phytosustainability in high levels of salinity and toxic trace elements. In: E. Frossard et al. (eds.) Function of soils for human societies and the environment. Special Publication of the Geological Society, London, England. 266:79-88. 2006.
102. Pasakdee, S., **G.S. Bañuelos**, C. Shennan, and W. Cheng. Organic N. fertilizers and Irrigation influence organic broccoli production in two regions of California. *Journal of Vegetable Science*, 12(4): 27-46. 2006.
103. **Bañuelos, G.S.** Production of unique biobased products from vegetation management

of selenium. In: Y. Zhu (eds.) Biogeochemistry of trace elements: environmental protection, remediation and human health. Tsinghua Press, Beijing, China. 2007.

104. **Bañuelos, G.S.** and Z.Q. Lin. Acceleration of selenium volatilization in seleniferous agricultural drainage sediments amended with methionine and casein. *Journal of Environmental Pollution*, 150:306-312. 2007.
105. **Bañuelos, G.S.**, D.L. LeDuc, E.A.H. Pilon-Smits, A. Tagmount, and N. Terry. Transgenic Indian mustard overexpressing selenocysteine lyase, selenocysteine methyltranferase, or methionine methyltansferase exhibit enhanced potential for selenium-contaminated sediments. *Environmental Science and Technology*, 41:599-605. 2007.
106. **Bañuelos, G.S.**, S. Pasakdee, S.E. Benes and C.A. Ledbetter. Long-term application of biosolids on apricot production. *Communications Soil Science Plant Analysis*, 38: 1533-1546. 2007.
107. Gao, S., Tanji, K. K., Bañuelos, G. S. Processes and conditions affecting elevated arsenic concentrations in groundwaters of Tulare Basin, California, USA. *Trace Metals and other Contaminants in the Environment*, 9: 383-410. 2007.
108. **Bañuelos, G.S.** Canola crop takes up selenium, provides biofuel and feed supplement. California State University, Fresno, CATI-ARI Publication #03-2-002 June issue. 2008
109. Luthria, D.L., LZ. Lin, R.J. Robbins, J.W. Finley, **G.S. Bañuelos** and J.M. Harnly. Discriminating between cultivars and treatments of broccoli using mass spectral fingerprinting and analysis of variance-principal component analysis. *Journal of Agricultural and Food Chemistry*, 56: 9819-9827. 2008.
110. Luthria, D.L., R.J. Robbins, J.W. Finley, **G.S. Bañuelos**, J.M. Harnly, R.J. Robbins. UV spectral fingerprinting and analysis of variance-principal component analysis: a useful tool for characterizing sources of variance in plant materials. *Journal of Agriculture and Food Chemistry*, 56: 5457-5462. 2008.
111. **Bañuelos, G.S.** Amelioration and conversion of excessive selenium to new resources from a plant-based system. In: G.S. Bañuelos et al. (eds.) Selenium deficiency, toxicity, and biofortification for human health. USTC Press, Hefei, China. 2009.
112. **Bañuelos, G.S.** Phytoremediation of selenium-contaminated soil and water produces biofortified products and new agricultural byproducts. In: G.S. Bañuelos, and Z.Q. Lin. (eds.) Biofortification and development of new agricultural products. CRC Press, Boca Roca FL. pp. 57-70. 2009.
113. **Bañuelos, G.S.** and Z.Q. Lin. (eds.) Biofortification and development of new agricultural products. CRC Press, Boca Roca FL. 2009.
114. **Bañuelos, G.S.**, Z.Q. Lin, and X. Yin (eds.). Selenium deficiency, toxicity and biofortification for human health. University of Science and Technology of China Press, Hefei, China. ISBN 978-7-312-02592. 2009.
115. Robinson, B.H., **G.S. Bañuelos**, H.M. Conesa, M.W.H. Evangelou, and R. Schulin. The phytomanagement of trace elements in soil. *Critical Reviews in Plant Science*, 28: 1-27. 2009.
116. Singh, A.P., D. Luthria, T. Wilson, N. Vorsa, V. Singh, **G.S. Bañuelos**, and S. Pasakdee. Polyphenols content and antioxidant capacity of eggplant pulp. *Food Chemistry*, 114:955-961. 2009.
117. Stapleton, J.J. and **G.S. Bañuelos**. Biomass crops can be used for biological disinfestation and remediation of soils and water. *California Agriculture*, 63: 41-46.

2009.

118. **Bañuelos, G.S.** and B. Hanson. Use of selenium-enriched mustard and canola seed meals as potential bioherbicides and green fertilizer in strawberry production. *Horticultural. Science*, 45:1-6. 2010.
119. **Bañuelos, G.S.** and R. Schulin. Use of Opuntia (cactus) and Brassica for the management of selenium in the westside of the central California. *In*: T.A. Herrera (eds.) *Frontiers in Trace Elements Research and Education*. Chihuahua Press, Chihuahua, Mexico. ISBN: 978 607-7788-24-9. 629pp. 2010.
120. **Bañuelos, G.S.** and Z.Q. Lin. Cultivation of Indian Fig Opuntia in selenium-laden agriculture drainage sediments under field conditions. *Journal of Soil and Land Management*, 26:167-175. 2010
121. **Bañuelos, G.S.**, J. Gao, Y. Lin, Y. Huang, Z.Q. Lin, Hon Wah Lam, M., and X. Yin. Daily selenium intake in a moderate selenium deficiency area of Suzhou, China. *Food Chemistry*, 126(3):1088-1093. 2010.
122. **Bañuelos, G.S.**, J. Robinson and J. daRoche. Developing selenium-enriched animal feed and biofuel from canola planted for managing Se-laden drainage waters in the Westside of central California. *International Journal of Phytoremediation*, 12:243-253. 2010.
123. Bitterli, C., **Bañuelos, G.S.** and R. Schulin. Use of transfer factors to characterize uptake of selenium by plants. *Journal of Exploratory Geochemistry*, 107:206-216. 2010.
124. Luthria, D., A.P. Singh, T. Wilson, N. Vorsa, **G.S. Bañuelos** and B.T. Vinyard. Influence of conventional and organic agricultural practices on the phenolic content in eggplant pulp: Plant-to-plant variation. *Journal of Agricultural and Food Chemistry*, 121:406-411. 2010.
125. **Bañuelos, G.S.** Biological production of selenium-biofortified products from natural-occurring sources of selenium. *In*: Bañuelos, G.S., Z.-Q. Lin, X.B. Yin, and N. Duan (eds.) Selenium: global perspectives of impacts on humans, animals and the environment. University of Science and Technology of China Press, Hefei. 2011.
126. **Bañuelos, G.S.** and K. Dhillon. Developing a sustainable phytomanagement strategy for excessive selenium in western United States and India. *International Journal of Phytoremediation*, 13:208-222. 2011.
127. **Bañuelos, G.S.**, D. Leduc and J. Johnson. Evaluation of hybrid poplar tree tolerance to irrigation with high salinity under microplot conditions. *Journal of International Phytoremediation*, 12:419-439. 2011.
128. **Bañuelos, G.S.**, S.C. Fakra, S.S. Walse, M.A. Marcus, S.I. Yang, I.J. Pickering, E.A.H. Pilon-Smits, and J.L. Freeman. Selenium accumulation, distribution, and speciation in spineless prickly pear cactus: a drought-and salt-tolerant, selenium enriched nutraceutical fruit crop for biofortified food. *Plant Physiology*, 155:315-327. 2011.
129. **Bañuelos, G.S.**, Z.-Q. Lin, X.B. Yin, and N. Duan. Selenium: global perspectives of impacts on humans, animals and the environment (editors). University of Science and Technology of China Press, Hefei. 2011.
130. Colin, F.Q., C.N. Prins, J.L. Freeman, A.M. Gross, L.J. Hantzis, R.J.B. Reynolds, S.I. Yang, P.A. Covey, **G.S. Bañuelos**, I.J. Pickering, S.C. Fakra, M.A. Marcus, H.S. Arathi and E.A.H. Pilon-Smits. Selenium accumulation in flowers and its effects on pollination. *New Phytologist*, 192(3):727-737. 2011.

131. Freeman, J.L. and **G.S. Bañuelos**. Selection of Salt and Boron Tolerant Selenium Hyperaccumulator Stanleya pinnata Genotypes and Characterization of Se Phytoremediation from Agricultural Drainage Sediments. *Environmental Science & Technology*, 45(22):9703–9710. 2011.
132. Gao, J., Y. Liu, Y. Huang, Z.-Q. Lin, **G.S. Bañuelos,** M.H. Lam, and X. Yin. Daily selenium intake in a moderate selenium deficiency area of Suzhou, China. *Food Chemistry*, 126:1088-1093. 2011.
133. J. Hong, **G.S. Bañuelos**, T. Fowler, and Z.-Q. Lin. Use of Selenium-Laden Plant Materials from Phytoremediation to Produce Selenium-Biofortified Edible Mushrooms. ICOBTE 2011, 11th international conference on the biogeochemistry of trace elements. 2011.
134. **Bañuelos, G.S.**, C. Stushnoff, S. Walse, T. Zuber, I. Pickering, G. George, I. Y. and J. Freeman. Characterization of the nutritional components in fruit and cladode of selenium-enriched nutraceutical cactus pear fruit varieties grown on agricultural sediment. *Food Chemistry*, 135:9-16. 2012.
135. **Bañuelos, G.S.**, S. Walse, S.I. Yang, I.J. Pickering, S.C. Fakra, M.A. Marcus and J.L. Freeman. Quantification, localization and identification of selenium in seeds of canola and two mustard species compared to seed meals produced by hydraulic press. *Analytical Chemistry*, 84(14):6024-6030.
136. **G.S. Bañuelos**, J. Ayars, Z. Q. Lin. Reuse/disposal of agricultural drainage water with high levels of salinity and toxic trace elements in central California. Zueng-Sang Chem (Ed). International Remediation and Management of Soil and Groundwater Contaminated Sites. National Taiwan Uni. Press, Taipei, Taiwan.pp. 207-215. 2012.
137. **Bañuelos, G.S.**, C. Bitterli, and R. Schulin. Fate and movement of selenium from drainage sediments disposed onto soil with and without vegetation. *Environmental Pollution*, 180:7-12. 2013.
138. **Bañuelos, G.S.**, K.S. Dhillon and S.S. Banga. Oilseed brassicas. *In*: B.P. Singh (ed.) *Biofuel Crops: Production, Physiology and Genetics*. CABI International, Wallinford, Oxfordshire, UK. Pp. 339-368. 2013.
139. **Bañuelos, G.S.**, Lin Z.-Q., Yin, X.B., and N. Duan. Selenium in the Environment and Human Health (editors). The Netherlands: CRC Press/Balkema. p.234. 2013
140. **G.S. Bañuelos**. Plants used in the phytomanagement of selenium may be useful for producing selenium-biofortified plant products. *In*: G.S. Bañuelos, Z.-Q. Lin, X.B. Yin, and N. Duan. (eds.) *Selenium in the Environment and Human Health*. The Netherlands: CRC Press/Balkema. 2013.
141. Huang, Y., Q. Wang, J. Gao, ZQ, Lin, Z., **G.S. Bañuelos**, and X.B. Yin. Daily selenium intake and hair content in a high selenium area of Enshi, China. *Nutrients*, 5:700-710. 2013.
142. Pilon-Smits, E.A.H., **G.S. Bañuelos**, and D.R. Parker. Uptake, Metabolism, and volatilization of selenium by terrestrial plants. *In*: A.C. Chang and D.B. Silva (eds.) *Drainage and Salinity in the San Joaquin Valley: Science, Technology and Policy*. Springer. Dordrect, Heidelberg. Pp147-164. 2013.
143. Schmidt R., P. Tantoyotai, S.C. Fakra, M.A. Marcus, S.I. Yang, I.J. Pickering, **G.S. Bañuelos**, K. Hristova, J.L. Freeman. Selenium Biotransformations in an Engineered Aquatic Ecosystem for Bioremediation of Agricultural Wastewater via Brine Shrimp Production. *Environmental Science and Technology*, 47(10):5057-5065. 2013.

144. Yuan, L.Y. Qi, Y. Zhu, X. Yin, and **G.S. Bañuelos**. A novel selenocystine-accumulating plant in selenium-mine seepage area of Yutangba, China. *PLOS ONE*, 8(6):1-9. 2013.
145. Li, M., G.P. Sheng, Y.J. Wu, Z.L. Yu, **G.S. Bañuelos,** and H.Q. Yu. Enhancement of nitrogen and phosphorus removal from eutrophic water by economic plant annual ryegrass (Lolium multiflorum) with ion implantation. *Environmental Science and Pollution Research International*. (accepted 2014).
146. Li, S., **G.S. Bañuelos,** L. Wu, and W. Shi. The changing selenium nutritional status of Chinese residents. *Nutrients*, 6:1103-1114. 2014.
147. Shrestha, A., A. Rodriguez, S. Pasakdee and **G.S. Bañuelos**. Efficacy of white mustard and soybean meal as a bioherbicide in organic broccoli and spinach production. *Communications in Plant and Soil Analysis*. (DOI: 10.1080/00103624.2014.956884 2014).
148. Wu, Z., X. Yin, Z.-Q. Lin, **G.S. Bañuelos,** L. Yuan, Y. Liu, and M. Li. Inhibitory effect of selenium against *Penicillium expansum* and its possible mechanisms of action. *Current Microbiology* (accepted; doi.10.1007/ss00-284-014-0573-0). 2014.
149. Wu, Z.-L., X.-B. Yin, Z.-Q. Lin, **G.S. Bañuelos,** L.-X. Yuan, Y. Liu, and M. Li. Inhibitory effect of selenium against *Penicillium expansum* and its possible mechanisms of action. *Current Microbiology*. (accepted 2014).
150. **Banuelos, G.S**., I.Arroyo, I.J. Pickering, S.I. Yang, and J.L. Freeman. Selenium biofortification of broccoli and carrots grown in soil amended with Se-enriched hyperaccumulator *Stanleya pinnata*. *Food Chemistry*. 166:603-608. 2015. (doi.org/10.1016/j.foodchem.2014.06.071).
151. **Banuelos, G**.S. Coping with naturally high levels of soil salinity and boron in the westside of Central California. *Perspective in Science* (accepted). 2014.

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EDUCATION

Ph.D. Dept. of Environmental Systems Science (May 2005)
Swiss Federal Institute of Technology Zurich (ETHZ), Switzerland
(Prof. Dr. Emmanuel Frossard and Prof. Dr. Hannes Flühler, advisors)

M.S. Agricultural, Food, and Environmental Sciences (July 1999)
Concentration in Plant Eco-physiology
Marche Polytechnic University, Ancona, Italy

B.S. Agricultural Sciences (July 1997)
Minor in Sustainable Agriculture
Marche Polytechnic University, Ancona, Italy

ACADEMIC APPOINTMENTS

Research Associate. California State University Fresno, Center for Irrigation Technology, United States of America (2012 – present)

Research Associate. University of Maryland College Park, Dept. of Civil and Environmental Engineering, United States of America (2007- 2012)

Post-doctoral Scholar. Cranfield University, Environmental Science and Technology Dept., United Kingdom (2006-2007)

Research Assistant. Marche Polytechnic University, Dept. of Environment and Crop Science, Italy (1999-2001)

TEACHING, MENTORING, and SUPERVISING

Co-instructor. Plant Nutrition (PL250T) 3-units, graduate course, California State University Fresno (Spring 2014)

Lab Assistant. Soil chemistry and biology laboratory, undergraduate lab course, Swiss Federal Institute of Technology Zurich (ETHZ) (Fall 2003 and Fall 2004)

Guest lecturer. Seminar series on farming and environmental sustainability, Marche Polytechnic University, Ancona, Italy (Winter 2001)

Mentor. Lab assistant, Biochemistry graduate student from California State University Fresno (Student's name: Justin King; August 2013 – present)

Mentor. Summer Research Intern, SEED program for Talented and Economically Disadvantaged High School Students sponsored by American Chemical Society (www.acs.org/content/acs/en/education/students/highschool/seed) (Student's name: Christian Garcia, Reedley High School; summer 2014, 9 weeks internship)

Mentor. Summer lab assistant intern, USDA Junior Agricultural Ambassador internship and leadership program for high school students through Hispanic-serving Institution National Program (www.hsi.usda.gov/Students/JAAP) (Student's name: Abigail Vidrio, Orange Cove High School; summer 2014, 6 weeks internship)

Supervisor. Visiting Ph.D. student from University of Udine, Italy (Student's name: Guido Fellet; January – July 2008)

Supervisor. Visiting Ph.D. student from Institute of Agro-biological investigations of Galicia, Spain (Student's name: Maribel Cabello-Conejo; January – June 2011)

CURRENT AND PAST RESEARCH GRANTS

California Energy Commission: An innovative project to turn energy beets into biofuels, co-investigator, total budget $5,000,000 (2012-2017)

U.S. Department of Agriculture, Cooperative Research, Education, and Extension Service: Developing sustainable vineyard water management strategies for limited and impaired water supplies, Senior Personnel, total budget $1,200,000 (2011-2014)

California Table Grape Commission: Determining nutritional quality in sustained deficit irrigated grapes, co-investigator, total budget $19,000 (2013)

Environmental Protection Agency: *In situ* remediation of DDT and Dieldrin residues in old orchard soils at Beltsville Agricultural Research Center, co-investigator, total budget $200,000 (2011-2013)

PUBLICATIONS

Book chapters:

1. **Centofanti T.** 2015. Phytoextraction of trace metals – principles and applications. *In*: Environmental Sustainability: the role of green technology. Thangavel P. and Sridevi G. (eds.) Springer Publishing. New York, USA. pp: 217-227.
2. Chaney R.L., Baklanow I.A., **Centofanti T.** Broadhurst C.L., Baker A.J.M, Reeves R.D., van der Ent A., Roseberg R.J. 2014. Phytoremediation and phytomining: Using plant to remediate contaminated or mineralized environments. *In*: Plant Ecology and Evolution in Harsh Environments. Rajakaruna N., Boyd R. and Harris T. (eds.) Nova Science Publishers, Inc. NY, USA. pp: 365-392.
3. Chaney R.L., Broadhurst C.L., **Centofanti T.** 2010. Phytoremediation of soil trace elements. *In*: Trace elements in soils. Hooda P.S. (eds.). John Wiley & Sons, Ltd. Chichester, UK. pp: 311-339.

Peer-reviewed journal articles:

1. Andrade N. A, **Centofanti T.**, McConnell L.L., Hapeman J.C., Torrents A., Nguyen A., Beyer N.W., Chaney R.L., Novak J.M., Anderson M. O., Cantrell K.B. 2014.

Utilizing thin-film polymer solid-phase extraction to assess the effect of organic carbon amendments on the bioavailability of DDT and dieldrin to earthworms. Environmental Pollution. 185:307-313.

2. **Centofanti T.**, Sayers Z., Davis A.P., Sicher R.S., Cabello-Conejo M.I., Kidd P.S., Kakei Y. Nishizawa N.K., Chaney R.L. 2013. Xylem composition and root-to-shoot Ni translocation in *Alyssum* species. Plant and Soil. 373:59-75.
3. Cabello-Conejo M.I., **Centofanti T.**, Kidd P.S., Prieto-Fernandez A., Chaney R.L. 2012. Evaluation of plant growth regulators to increase Ni phytoextraction by *Alyssum* species. International Journal of Phytoremediation. 15:365-375.
4. **Centofanti T.**, Siebecker M.G., Chaney R.L., Davis A.P., Sparks D.L. 2012. Hyperaccumulation of nickel by *Alyssum corsicum* is related to solubility of Ni mineral species. Plant and Soil. 359:71-83.
5. **Centofanti T.**, Tappero R.V., Davis A.P., Chaney R.L. 2011. Chelator-buffered nutrient solution is ineffective in extracting Nickel from seeds of *Alyssum*. International Journal of Phytoremediation.13:434-440.
6. Chaney R.L., Fellet G., Torres R., **Centofanti T.**, Green C. E., Marchiol L. 2009. Using chelator-buffered nutrient solution to limit Ni phytoavailability to the Ni-hyperaccumulator *Alyssum murale.* Northeastern Naturalist. 16 (special Issue 5):215-222.
7. Fellet G., **Centofanti T.**, Chaney R.L., Green C.E. 2009. NiO(s) (bunsenite) is not available to Alyssum species. Plant and Soil. 319:219-223.
8. **Centofanti T.**, Hollis J.M., Blenkinsop S., Fowler H.J., Truckell I., Dubus I.G. and Reichenberger S. 2008. Development of agro-environmental scenarios to support pesticides risk assessment in Europe. Science of the Total Environment. 407:574-588.
9. **Centofanti T.**, Flühler H., Frossard E. 2007. Time-dependent distribution of surface-applied radionuclides and their recovery in maize during the growing season. Journal of Environmental Quality. 36:280-290.
10. **Centofanti T.** and Frossard E. 2006. Uptake and translocation of 134Cs by maize roots as affected by heterogeneous distribution of 134Cs. Plant and Soil. 284:293-303.
11. **Centofanti T.**, Penfield R., Albrecht A., Pellerin S., Flühler H. Frossard E. 2005. Is the transfer factor the relevant tool to assess the soil-to-plant transfer of radionuclides under field conditions? Journal of Environmental Quality. 34:1972-1979.

PUBLICATIONS IN PREPARATION (to be submitted in the next 6 months)

1. **Centofanti T.** and Bañuelos, G.S. 2014. Evaluation of the halophyte *Salsola soda* as alternative crop for saline soils high in selenium and boron. Submitted to Journal of Environmental Management (December 2014).
2. **Centofanti T.,** Wallis C., Bañuelos G.S. 201X. Physiological responses of pomegranate trees grown on saline and Se and B contaminated soils.
3. Albrisqueta I., **Centofanti T.**, Ayars J. E., Bañuelos G.S. 201X. Effects of vineyard water management strategies for limited and impaired water supplies on yield and fruit quality.

4. Anderson M.O. **Centofanti T.**, McConnell L.L., Hapeman J.C., Torrents A., Nguyen A., Beyer N.W., Davis A.P., Chaney R.L. 201X. Effectiveness of organic amendments and plant cover for *In situ* remediation of DDT and Dieldrin residues in old orchard soils.
5. **Centofanti T.,** Wallis C., Bañuelos G.S. 201X. Is cactus (*Opuntia Ficus-Indica*) a viable alternative crop for the arid and saline soils in West America?
6. Zambrano C., **Centofanti T.,** Bañuelos G.S. 201X. Potential use of effluent waste from sugar beet ethanol production as fertilizer.

CONFERENCE PAPERS

1. Rodriguez A., Zoldoske T., **Centofanti T.**, Bañuelos G.S. Discovering potential neutraceuticals in drought and salt tolerant pomegranates grown with poor quality water in central California. 2013 Water resources and Policy Initiatives Conference. June 20-22, 2013, Long Beach, CA.
2. Andrade N. A, **Centofanti T.**, McConnell L.L., Hapeman J.C., Torrents A., Beyer N.W., Chaney R.L., Novak J.M., Anderson M. O., Cantrell K.B. Utilizing thin-film polymer solid-phase extraction to assess the effect of organic carbon amendments on the bioavailability of DDT and dieldrin to earthworms. SETAC North America 32nd Annual Meeting, November 13-17, 2011, Boston, MA.
3. **Centofanti T.**, Sayers Z., Cabello-Conejo M.I., Kidd P.S., Davis A.P., Sicher R.C., Chaney R.L. Determination of nickel chelators in xylem sap of *Alyssum* at steady-state nickel uptake. 11th International Conference of the Biogeochemistry of trace elements. July 3-7, 2011, Florence, Italy.
4. **Centofanti T.**, Siebecker M.G., Davis A.P., Sparks D.L., Chaney R.L. Phytoavailability of Ni Compounds to Alyssum Species*.* 6th International Phytotechnology Conference, December 1-4, 2009, St. Louis, MO.
5. **Centofanti T.**, Hollis J., Truckell I., Fowler H., and Blenkinsop P. Identification of Agro-environmental scenarios characterizing European Agriculture. XIII Symposium on Pesticide Chemistry, September 3-6, 2007, Piacenza, Italy.
6. **Centofanti T.** and Frossard E. Uptake and translocation of ^{134}Cs by a fraction of the root system of maize as affected by K supply. International Plant Nutrition Colloquium, September 14-19, 2005, Beijing, China.
7. **Centofanti T.**, Penfield R., Albrecht A., Flühler H. and Frossard E. Uptake of ^{134}Cs by a small fraction of maize root growing in ^{134}Cs enriched areas. RHIZOSPHERE Congress 2004, September 12-17, 2004, Munich, Germany.
8. **Centofanti T.**, Penfield R., Albrecht A., Kulli B., Flühler H., Frossard E. Factors controlling ^{54}Mn, ^{65}Zn, ^{57}Co and ^{134}Cs uptake by maize. 7th ICOBTE, June 15-19, 2003, Uppsala, Sweden.
9. **Centofanti T.**, Penfield R., Albrecht A., Kulli B., Flühler H., Frossard E. Effects of soil structure on the displacement of surface-applied radionuclides and root distribution. International workshop “Rhizosphere, preferential flow and bioavailability: A holistic view of soil-to-plant transfer”, September 21-26, 2002, Ascona, Switzerland.

10. **Centofanti T.**, Penfield R., Albrecht A., Flühler H. and Frossard E. ^{65}Zn, ^{54}Mn, ^{57}Co and ^{134}Cs uptake by maize grown under field and pot conditions. Preliminary results. SETAC Europe 12th Annual meeting, May 12-16, 2002, Vienna, Austria.

PEER REVIEW SERVICE

Reviewer for: Agriculture, Ecosystems and Environment; Journal of International Phytoremediation; Environmental Science & Technology; Journal of Environmental Radioactivity; Science of the Total Environment; Plant Growth Regulation; Annals of Botany PLANTS.

ASSOCIATIONS

American Chemical Society (ACS)

PUBLIC INVOLVMENT

"Drought-stressed crop may be better for you". The California Report Statewide Radio Program/KQED Public Radio, by Sasha Kohkha, October 20, 2014.
http://blogs.kqed.org/science/audio/drought-stressed-crops-may-be-better-for-you/
and
http://www.npr.org/blogs/thesalt/2014/10/23/357909950/why-californias-drought-stressed-fruit-may-be-better-for-you

Hui Zhu

Curriculum vitae

Name: Hui ZHU
Date of Birth: 01.08.1983
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Academic degree: Ph. D
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Education

Ph.D. Environmental Science 2011
Northeast Institute of Geography and Agroecology, CAS, China
M.Sc. Environmental Science 2008
Northeast Normal University, China
B.Sc. Environmental Science 2006
Jilin Institute of Chemical Technology, China

Appointment

2014-present Associate Researcher
Northeast Institute of Geography and Agroecology, CAS, China

2011-2013 Research Assistant
Northeast Institute of Geography and Agroecology, CAS, China

Membership in professional societies

International Water Association (IWA)
Chinese Society for Environmental Sciences

Research interests

My research interests include the biogeochemical processes of nutrients, heavy metals and other contaminants in surface waters (rivers, lakes, wetlands) and farmlands, the risk assessment and remediation of environment pollution. My current efforts is directed towards developing ecological technologies for water treatment, e.g. constructed wetlands, ecological ditches, etc.

Research grants

Supervising the Natural Science Foundation Project of China "Effect of ground water (containing high concentrations of iron and manganese) irrigation on nitrogen transformation characteristics in paddy field in Sanjiang Plain, China" (2015-2018);

Supervising the Natural Science Foundation Project of China "Effect of exogenetic iron on

nitrogen loss from paddy field in Sanjiang Plain, China" (2012-2014);

Supervising one sub-project "Space-time evolution of large-scale coast reclamations in major delta coastal wetlands of China" of the National Basic Research Program (973) of China "Space-time evolution of large-scale coast reclamations and the change of landscape ecological structure in major delta coastal wetlands of China" (2013-2017);

Supervising the Open Research Fund Project of Key Laboratory of Mollisols Agroecology, CAS "Effect of hydrothermal conditions change on nitrogen migration and transformation in black soil" (2012-2014);

Supervising one sub-project "Investigation of the pollution loads in Khanka Lake Basin, Northeast China" of the Baseline Survey Program on Khanka Lake, Northeast China (2013-2014);

Supervising one sub-project "Nonpoint source pollution loads in Sanjiang Plain and its influence on the water quality" of the Knowledge Innovation Project of Chinese Academy of Sciences "Sustainable use of water resources in the process of agricultural development and wetland protection" (2009-2011).

Awards

Excellent staff award in Northeast Institute of Geography and Agroecology, CAS, 2013;

"Zhu Li Yuehua outstanding doctoral scholarship in CAS" award, 2011;

"Third Prize of Jilin Province Science & Technology Development" award, 2011;

The best poster award in IWA 14th International Conference on Wetland Systems for Water Pollution Control", 2014.

Current research activities about constructed wetlands

The feasibility of using constructed wetland and eco ditches to treat the drainage water from paddy field in Sanjiang Plain, China. The natural wetland in Sanjiang Plain degraded seriously because of the lack of water, however, the drainage water from paddy field was discharged into rivers, causing water pollution. Therefore, investigation was conducted to discuss the feasibility of using constructed wetland and eco-ditches to treat the drainage water and using the water for supplying the natural wetlands. This work has been finished in 2013.

Effect of plant diversity on the purification ability of horizontal subsurface flow constructed wetlands and their performance under low temperature. A series of simulation wetlands were built by planting canna, willow herb, and the mixture of these two plants. The purification ability of constructed wetlands to domestic sewage in common temperature and low temperature were compared, the rhizosphere microenvironment was also investigated. This work is supposed to be finished in 2015.

Purification of domestic sewage and pig farm wastewater by surface flow constructed wetland with different plant species in subtropical region. Two series of scale constructed wetlands were built in two villages in Fujian Province, for domestic sewage and pig farm wastewater treatment,

respectively. Ten plant species were planted in constructed wetlands, and their purification abilities, biomass, economic cost will be compared. This work is supposed to be finished in 2015.

Enhancement measures for constructed wetlands under low temperature. We are doing research on intensifying the purification ability of constructed wetlands by using the artificial aeration method, and by introducing the active medium, etc. This research is supposed to be finished in 2016.

International publications scientific reviewer

Water Research, Ecological Engineering, Chinese Geographical Science, Surface and Coatings Technology, British Journal of Environment and Climate Change, Environmental Engineering and Management Journal, International Journal of Phytoremediation, Desalination and Water Treatment.

Publications (peer reviewed)

1. **Zhu H**, Yan BX, Liu SY, et al. Removal of nitrogen and COD in horizontal subsurface flow constructed wetlands under different influent C/N ratios. Ecological engineering. 2014, 63: 58-63.
2. **Zhu H**, Zhu LL, Yan BX, et al. Accumulation of Lead, Zinc, and Copper in Scalp Hair of Residents in a Long-Term Irrigation Area Downstream of the Second Songhua River, Northeast China. Human and ecological risk assessment. 2014, 20:137-149.
3. **Zhu H**, Yan BX, Shahbaz K, et al. Nitrogen loss via lateral seepage from paddy field: A case study in Sanjiang Plain, Northeast China. Journal of Food, Agriculture and Environment. 2013, 11(1):841-845.
4. **Zhu H**, Yan BX, Cao HC, et al. Risk assessment for methylmercury in fish from the Songhua River, China: 30 years after mercury-containing wastewater outfalls were eliminated. Environmental Monitoring and Assessment. 2012, 184:77-88.
5. **Zhu H**, Xu YY, Yan BX, et al. Snowmelt runoff: A new focus of urban nonpoint source pollution. International Journal of Environmental Research and Public Health. 2012, 9(12), 4333-4345.
6. **Zhu H**, Yan BX, Pan XF, et al. Geochemical characteristics of heavy metals in riparian sediment pore water of Songhua River, Northeast China. Chinese Geographical Science. 2011, 21(1): 195-203.
7. **Zhu H**, Yan BX. Analysis of correlations among mercury, iron and manganese in sediment of the Songhua River. Advanced Materials Research. 2012, (518-523):1451-1451.
8. Zhang Y, **Zhu H**※, Yan BX, et al. Nutrient removal in different overlying water layers and their variation in pore water of drainage ditches in Sanjiang Plain, Northeast China. Desalination and Water Treatment. 2013, 51:5599-5607.
9. Zhang Y, **Zhu H**※, Yan BX. Vertical distribution and temporal variation of nitrogen, phosphorous and carbon in ditch sediment in Sanjiang Plain, Northeast China. Fresenius Environmental Bulletin. 2013, 22(8):2265-2272.
10. Zhang Y, **Zhu H**※,Yan BX. Effects of plant and water level on nitrogen variation in overlying and pore water of agricultural drainage ditches in Sanjiang Plain, Northeast China. CLEAN - Soil, Air, Water. 2014,42(2):386-392.
11. Xu YY, Yan BX, **Zhu H**※. Nutrient composition of paddy leaf dew in Sanjiang Plain, China. Acta Agriculturae Scandinavica, Section B. 2013, 63, (2):97-106.
12. Xu YY, Yan BX, **Zhu H**※. Dew Condensation Monitoring in a Wetland Ecosystem in the Sanjiang Plain. Fresenius Environmental Bulletin. 2013, 22(5): 1351-1356.

13. Xu YY, Yan BX, Luan ZQ, **Zhu H**※. Dewfall variation by large-scale reclamation in Sanjiang Plain. Wetland. 2012, 32(4):783-790.
14. Yang YH, Yan BX, **Zhu H**. Estimating soil erosion in Northeast China using ^{137}Cs and ^{210}Pbex. Pedosphere. 2011, 21(6): 706-711.
15. Yang YH, Yan B, **Zhu H**. Effects of water and soil conservation practices on reducing pollution from agricultural nonpoint source in Northeast China. Advanced Materials Research.2012, 356-360:2473-2478.
16. Xu YY, Yan BX, **Zhu H**. Dew amount in marsh monitoring in the Sanjiang Plain. Applied Mechanics and Materials. 2014, 522-524: 34-37.
17. Xu YY, Yan BX, **Zhu H**. Dewfall monitoring in wetland ecosystem. Advanced Materials Research. 2014, 864-867: 883-886.
18. Xu YY, Yan BX, **Zhu H**. Meteorological Factors Affected Dew Condensation in Marsh Ecosystem. Applied Mechanics and Materials. 2014, 535: 360-363.
19. Xu YY, Yan BX, Luan ZQ, **Zhu H**. Application of stable isotope tracing technologies in identifying the transformation among waters in the Sanjiang Plain. Chinese Geographical Science. 2013,23:435-444.
20. Liu XQ, Yan BX, Liu SY, **Zhu H**. Influence of outside environmental variations on ammonia nitrogen adsorption characteristics of HVMT/PC/EPDM composite. Environmental Earth Science. 2013, 69:2541-2548.
21. Wang LX, Yan BX, Pan X, **Zhu H**. The spatial and temporal variation and factors controlling the concentration of total dissolve iron in rivers, Sanjiang Plain. Clean-Soil Air Water. 2012. 40(7):712-717.
22. Wang LX, Yan BX, Pan X, **Zhu H**. The Distribution and Output of Dissolved Carbon in Typical Rivers of Sanjiang Plain, China. Fresenius Environmental Bulletin. 2013, 22:508-515.
23. **Zhu H**, Yan BX. Export of nitrogen by lateral seepage from paddy field in Sanjiang Plain. Environmental Science. 2011, 32(1): 108-112. (in Chinese with English abstract)
24. **Zhu H**, Yan BX, Zhang FS. Effect of particle-sizes, pH and organic matter on adsorption and adsorption of mercury to sediments in the Songhua River. Environmental Science. 2010, 31(10): 2315-2320. (in Chinese with English abstract)
25. **Zhu H**, Yan BX. Export of phosphorus from paddy filed and its transport process in Sanjiang Plain. Wetland Science. 2010, 8(3): 266-272. (in Chinese with English abstract)
26. **Zhu H**, Yan BX, Zhang FS. Concentration of major components of sediments in the Songhua River to mercury adsorption. Environmental Chemistry. 2010, 29(5): 865-869. (in Chinese with English abstract)
27. **Zhu H**, Yan BX, Li HW. Total mercury and mercury species in sediments of Songhua River. Journal of Ecology and Rural Environment. 2010, 26 (3): 210-214. (in Chinese with English abstract)
28. **Zhu H**, Yan BX, Zhang FY. Enrichment of heavy metals in fishes of Songhua River and its pollution assessment. Journal of Ecology and Rural Environment. 2010, 26(5): 492- 496. (in Chinese with English abstract)
29. Zhang Y, **Zhu H**※, Yan BX, et al. Interception effect of ditch slag and sediments on nitrogen and phosphorus in water. China Environmental Science. 2013, 13(6):1005-1010. (in Chinese with English abstract)
30. Li Yuan, Yuan Xing, **Zhu H**※. Simulation study on effects of soil moisture contents on nitrogen transformation and enzyme activities in black soil. (in Chinese with English abstract)

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EDUCATION

Ph.D.	1998	*Soil-Water Physics - Agronomy*, University of Wyoming, Laramie, WY. Dissertation "Assessment of drip irrigation for managing nitrate contamination and sugar beet production in Wyoming"
M.S. + B.S.	1994	"Diplôme d'Ingénieur en Agriculture", *Agricultural Engineering*, Ecole Supérieure d'Agriculture d'Angers (E.S.A.), France.

PROFESSIONAL EXPERIENCE

- 2013-Present *Assistant Director of Research*, Center for Irrigation Technology, CSU Fresno
- 2012- Present *Assistant Professor*, Department of Plant Science, CSU Fresno.
- 2001-2012: *Soil and Water Scientist*, Center for Irrigation Technology, CSU Fresno.
- 2008-Present: *Adjunct Faculty*, Department of Plant Science, CSU Fresno.
- 1998-2001: Elected *Executive Council Member-at-Large* to the Pacific Division of American Association for Advancement of Sciences, San Francisco, CA.
- 1999-2000: *Research Scientist and Associate* (Post-Doctoral) of Soil-Water Sciences and Agronomy, Department of Plant Sciences, University of Wyoming, Laramie, WY.
- 1995-1998: *Research-Teaching Assistant* (Doctoral) of Soil-Water Physics & Environmental Sciences, Dpt of Renewable Resources, University of Wyoming, Laramie.

AWARD

2011 - *Coleman Fellowship* for "Entrepreneurship in Water Management and Irrigation Technology".
2011 - Recipient of Federal Labs Consortium, Western State Region.
2009 – *Outstanding Research and Scholarly Activity Award* – Jordan College of Agricultural Sciences and Technology, CSU Fresno.

AREAS OF EXPERTISE

- Crop production in irrigated systems, with emphasis on drip irrigation.
- Salinity monitoring and management.
- Remote sensing techniques (electromagnetic induction, satellite & aerial imagery) for water/soil resources management and pollution control at field/regional and watershed scales.
- Crop water requirements and crop coefficients; irrigation scheduling
- Irrigation system design and operation.

TEACHING EXPERIENCE

- Undergraduate and graduate courses taught in: Soil and Water Management; Irrigation Systems; Food, Society, and Environment; Agricultural Laboratory Techniques.
- Guest lectures for: Soils in the Environment (Lab); Research Methodology; Remote Sensing and GIS application; Applied Spatial Technology.

OUTREACH EXPERIENCE

- 2001-2010: Developed workshops and disseminated research results to international delegations (Australia, China, Egypt, Iraq, Israel, Japan), universities, federal, state and local agencies, growers, farm advisors. Topics: salinity management, use of electromagnetic induction technique.
- 2010: Participated in workshop for a US Marine Corps detachment. California State University Consortium for International Development (CID), Fresno, CA. Topics: salinity and water management, use of electromagnetic induction technique.
- 2007 and 2009: Organized field trips for Japanese and Israeli delegations (irrigation systems and water management of several Central Valley farms; salinity assessment).
- Gypsum Use in Agriculture. Two-day workshop for Japanese delegation (Fall 2007)
- Soil Salinity Assessment and Mapping Workshop: Theory and Practice, San Luis National Wildlife Refuge Office, Los Banos, CA (Spring 2005).
- Use of EM technique for soil and water management -workshop. Audience included students, faculties, scientists, engineers, farmers, and consultants from UC Davis, Lawrence Berkeley National Laboratory, and CSU Fresno (2002-2004).

PROFESSIONAL SERVICES

- 2014: *Member*, Soil and Water Conservation, Soil Science Society of America.
- 2011 - 2014: *Board Member, Scholarship Committee Chair, and Water Management Session Chair*, California Chapter of American Society of Agronomy.
- 2011 - 2014: *Member*, Planning committee, Multi-State Salinity Coalition.
- 2006 - 2014: *Member*, Research and Scholarly Activities Committee (RSAC), Jordan College of Agricultural Sciences and Technology, CSU Fresno.

MEMBERSHIPS

- Crop Science Society of America, Soil Science Society of America, American Society of Agronomy; California Chapter of American Society of Agronomy
- American Society of Horticultural Science
- American Society of Agricultural and Biological Engineers
- Irrigation Association

SELECTED FUNDINGS (total $4+ million)

- Agricultural Research Initiative – CSU. *Estimating water requirements and developing new crop coefficients for drip-irrigated crops in California's Central Valley*. $450,000 (2013-2017). F. Cassel S., D. Goorahoo, F. Melton, and L. Johnson.
- Agricultural Research Initiative – CSU. *Development of an integrated decision support system to optimize irrigation scheduling and water use efficiency*. $450,000 (2011-2014). F. Cassel S., D. Goorahoo, F. Melton, L. Johnson, C. Krauter, and L. Pierce.
- California Department of Water Resources. *Estimating leaching requirements in drainage reuse systems from soil salinity surveys*. $91,466 (2010-2014). F. Cassel S. and D. Zoldoske.
- JG Boswell Company. *Evaluating irrigation and cultural management alternatives through field-scale salinity and water table characterization*. $69,600 (2010-2012). F. Cassel S., D. Goorahoo, and B. Roberts.
- California Department of Water Resources. *IFDM – EM 38 Survey of Britz Farms*. $17,215 (2009). F. Cassel S. and D. Zoldoske.
- Agricultural Research Initiative – CSU. *Reclamation of Saline-Sodic Soils for Tomato Production using Calcium Fertigation and Acidification.* $90,000 (2008-2012). F. Cassel S. and D. Goorahoo.
- Agricultural Research Initiative – CSU. *Integrating Remote Sensing Techniques to Determine Extent of Salinity in San Joaquin Valley of California.* $250,000 (2008-2011). F. Cassel S., D. Zoldoske, and X. Yang.
- Westside Resource Conservation District. *Salinity Mapping at Red Rock Ranch and Britz Farm*. $14,283 (2006-2009). F. Cassel S.
- Agricultural Research Initiative - CSU. *Estimating crop evapotranspiration and soil salinity from remote sensing imagery*. $140,000 (2005-2008). F. Cassel S. and D. Zoldoske.
- Department of Water Resources - California Bay-Delta Authority. *Training and Development of Instructional Materials for Real-Time Salinity Management from Seasonal Wetlands*. **$**69,850 (grant extension) (2004-2005). N. Quinn and F. Cassel S.
- Agricultural Research Initiative - CSU. *Use of Remote Sensing Techniques for Improving Soil and Crop Management Practices*. $213,000 (2004-2007). F. Cassel S., M. Spiess, B. Taylor, and D. Zoldoske.
- United States Bureau of Reclamation. *Soil Hydraulic Properties and Salinity Assessment at Red Rock Ranch*. $75,000 (2003-2005). D. Goorahoo, F. Cassel S, and S. Benes.
- CALFED and California Department of Food and Agriculture - Agricultural Research Initiative. *Assessing Spatial and Temporal Variability of Soil salinity on Farms Implementing Integrated Drainage Management Practices*. $425,010 (2001-2006). F. Cassel S., D. Goorahoo, D. Zoldoske, and P. Canessa.

SELECTED PUBLICATIONS and PRESENTATIONS (selected)

Book chapters and peer-reviewed articles

- Goorahoo, D., **F. Cassel S.**, and S. Benes. 2011. Chapter 3 "Soil water and plant relations". *In* Irrigation 6th edition (eds L. E. Stetson and B. Mecham), Irrigation Association. p 23-73.
- **Cassel S., F.**, D. Goorahoo, D. Zoldoske, and D. Adhikari. 2009. *Mapping soil salinity using ground-based electromagnetic induction technique*". *In* G. Metternicht and A. Zinck (eds.), Remote Sensing of Soil Salinization: Impact on Land Management, Chapter 11, CRC Press, Boca Raton, FL, p. 199-233.
- **Cassel S., F.** 2007. "Soil Salinity Mapping Using ArcGIS". *In F.J. Pierce (ed.), GIS Applications for Agriculture*, CRC Press, Boca Raton, FL, Chapter 8, p. 141-162.
- **Cassel S., F.** and D. Zoldoske. 2006. Assessing canal seepage and soil salinity using the electromagnetic remote sensing technology. *In G. Lorenzini and C.A Brebbia (eds) Sustainable Irrigation management, Technologies and Policies.* WIT Press. p. 55-63.
- Goorahoo, D., E. Norum, **F. Cassel S.,** and D. Adhikari. 2004. *Development of a Standardized Testing Protocol for Soil Moisture Sensors.* International Water and Irrigation. 24(2):21-22.
- **Cassel S., F.**, D. Zoldoske, and M. Spiess. 2003. Assessing spatial and temporal variability of soil salinity on farms implementing integrated drainage management practices. CATI Publication #030603, Fresno, CA, 40 pp.
- **Cassel S., F.,** D. Zoldoske, T. Jacobsen, and E. Norum. 2002. *Using electromagnetic sensing technique for assessing soil salinity and canal seepage*. *In* G. Becciu et al. (eds) New Trends in Water and Environmental Engineering for Safety and Life, Capri, Italy. p. 89.
- **Cassel S., F.**, S. Sharmasarkar, S. Miller, G. Vance, and R. Zhang. 2001. Assessment of drip and flood irrigation on water and fertilizer use efficiencies for sugarbeets. *Agricultural Water Management*. 46(3):241-251.
- **Cassel S., F.**, S. Sharmasarkar, L. Held, S. Miller, G. Vance, and R. Zhang. 2001. Agro-economic analysis of drip irrigation for sugarbeet production. *Agronomy Journal*. 93:517-523.
- **Cassel S., F.**, S. Sharmasarkar, R. Zhang, G. Vance, S. Miller, and M. Reddy. 2000. Modeling nitrate movement in sugarbeet soils under flood and drip irrigation. *International Commission of Irrigation and Drainage Journal*. 49:43-54.
- **Cassel S., F.**, S. Sharmasarkar, S. Miller, L. Held, G. Vance, and R. Zhang. 2000. Assessment of microirrigation for sugarbeet production. *Journal of Sustainable Agriculture*. 17(2/3):17-32.
- **Cassel S., F.**, S. Sharmasarkar, R. Zhang, G. Vance, and S. Miller. 1999. Micro-spatial variability of soil nitrate following nitrogen fertilization and drip irrigation. *Water, Air, and Soil Pollution Journal.* 116:605-619.
- Reddy, M., D. Wilamowski, and **F. Cassel S**. 1999. Optimal scheduling of irrigation canal laterals. *International Commission of Irrigation and Drainage*. 48(3):1-12.

TECHNICAL and PROJECT REPORTS

1. **Cassel S., F,** and D. Goorahoo. 2014. Metrics for quantification of Agricultural Water Use Fraction (AWUF). Report submitted to CSUMB as part of ARI Project "Development of sustainability metrics for agricultural irrigation water use efficiency. 12 pp.

2. **Cassel S., F,** D. Goorahoo, F. Melton, L. Johnson, C. Lund, C. Krauter, and L. Pierce. 2014. Development of an integrated decision support system to optimize irrigation scheduling and water use efficiency. Annual report, California State University, Fresno. 5 pp.
3. **Cassel S., F,** D. Zoldoske, and X. Yang. 2013. Integrating remote sensing techniques to determine extent of salinization in the San Joaquin Valley of California. Final report, California State University, Fresno. 16 pp.
4. **Cassel S., F.** 2013. Salinity assessment at the New Jerusalem Drainage District. Report submitted as part of the Integrated Drainage and Irrigation Management Plan Task Order. 10 pp.
5. **Cassel S., F.**, D. Goorahoo, and B. Taylor. 2012. Reclamation of saline sodic soils for tomato production using calcium fertigation and acidification. Final report, California State University, Fresno. 16 pp.
6. **Cassel S., F**., D. Goorahoo, and B. Roberts. 2011. Soil salinity maps and data analyses for field 35NW. Interim report #4 as part of "Evaluating irrigation and cultural management alternatives through field-scale salinity and water table characterization". Submitted to: JG Boswell Company. March 25th 2011.
7. **Cassel S., F.** 2010. Electromagnetic induction technology measures soil moisture. Research report, California Agricultural Technology Institute. 4 pp.
8. **Cassel S., F.**, D. Zoldoske, and S. Mettler. 2008. Assessment of canal seepage using electromagnetic technique. Final report, ARI-CAST, California State University, Fresno, CA. 20 pp.
9. **Cassel S., F.** 2007. Investigation of potential seepage areas around the Oakes recharge basin. Final report, Kaweah Delta Water Conservation District, CA. 60 pp.
10. **Cassel S., F.,** D. Zoldoske, and S. Mettler. 2007. Assessing spatial and temporal variability of soil salinity on farms implementing integrated drainage management practices. Final report, ARI-CDFA, California State University, Fresno, CA. 44 pp.
11. **Cassel S., F.,** D. Zoldoske, and D. Goorahoo. 2007. Salinity assessment for precision farming in cotton systems. Final report, ARI-CAST, California State University, Fresno, CA. 14 pp.
12. **Cassel S., F.** 2007. Soil salinity appraisal in two agricultural fields. Final report, California State University, Fresno, CA. 26 pp.
13. **Cassel S., F.** 2005. Soil Salinity Assessment Manual – A guide for conducting soil salinity surveys, analyzing data, and generating maps. Manual developed for LBNL for project entitled "Real-Time Water Quality monitoring and Habitat Assessment in the San Luis National Wildlife Refuge", California DWR – CALFED Drinking Water Program. 22 pp.
14. Zoldoske, D., D. Goorahoo, **F. Cassel S.**, and G. Jorgensen. 2005. Evaluation of alternative saline drainage water disposal methods. Final report, ARI-CAST, California State University, Fresno, CA. 6 pp.
15. **Cassel S., F.** 2004. Estimating soil salinity in wetlands of the San Luis National Wildlife Refuge and Salinas Club. Research Report submitted to LBNL for CALFED project entitled "Real-Time Water Quality monitoring and Habitat Assessment in the San Luis National Wildlife Refuge", California DWR – CALFED Drinking Water Program. 8 pp.
16. **Cassel S., F.**, D. Zoldoske, and M. Spiess. 2003. Assessing Spatial and Temporal Variability of Soil Salinity on Farms Implementing Integrated Drainage Management Practices. Final Report. California DWR - CALFED Agricultural Water Use Efficiency Program, Sacramento, CA, 35 pp.

ABSTRACTS/PROCEEDINGS AND PRESENTATIONS

1. **Cassel S., F.**, and D. Goorahoo. 2014. Water requirements of drip-irrigated tomatoes in Central California. Proceedings, Technical conference, Irrigation Association, Orlando, FL.
2. **Cassel S., F.,** B. Dehghanmanshadi, D. Goorahoo, S. Ashkan, and M. DeWall. 2014. Optimizing Crop Biomass and Water Use Efficiency by Recycling CO_2 Emissions from Energy Production Systems. 2014 Asia Pacific Clean Energy Summit, Honolulu, Hawai`i.
3. Johnson, L., **F. Cassel S**., D. Goorahoo, and F. Melton. 2014. Calculator for Water Sustainability Metrics in California Agriculture. EWRI World Environmental and Water Resources Congress, Portland, OR. (Jun 3).
4. **Cassel S.,** F., D. Goorahoo, and P. Yadavali. 2013. Environmental and agronomic management strategies for improving tomato production in salt-affected soils of the San Joaquin Valley, CA. The Geological Society of America, Fresno, CA.
5. **Cassel S.,** F., D. Goorahoo, and P. Yadavali. 2011. Fertigation strategies to optimize tomato production In salt-affected soils. Abstracts Annual Meetings, American Society of Horticultural Science, HI.
6. Yadavali, P., D. Goorahoo, **F. Cassel S.**, and S. Benes. 2010. Evaluating different management strategies to increase calcium availability of tomatoes in saline sodic soils. Agronomy Abstracts Annual Meetings, ASA-CSSA-SSSA, Madison, WI.
7. Goorahoo, D., **F. Cassel S.**, and S. Benes. 2010. Reclamation and management strategies for salt affected agricultural lands in the San Joaquin Valley, CA. Canadian Society of Soil Science meeting, Saskatoon, Canada.
8. **Cassel S., F.** 2010. Salinity issues with crop production. Presentation at the "Rapid assessment of farming systems in Non-Secured Regions" workshop for a US Marine Corps detachment. California State University Consortium for International Development (CID), Fresno, CA.
9. Yadavali, P., **F. Cassel S.**, and D. Goorahoo. 2010. Comparison of three soil reclamation techniques for growing processing tomatoes in Westside SJV. Proceedings, 31st Annual Central California Research Symposium, Fresno, CA.
10. **Cassel S., F.**, D. Goorahoo, and P. Yadavali. 2010. Irrigation strategies for managing salt-affected soils in the San Joaquin Valley, CA. Proceedings, Multi-State Salinity Coalition, Las Vegas, NV.
11. Goorahoo, D., **F. Cassel S.**, and S.K.R. Yellareddygari. 2010. Remote sensing as an environmental and agricultural decision making tool for salinity management. Proceedings, Multi-State Salinity Coalition, Las Vegas, NV.
12. Yadavali, P., **F. Cassel S.**, and D. Goorahoo. 2010. Yield and quality of tomatoes subjected to calcium fertigation and acidification in saline-sodic soils. Proceedings, California Plant and Soil Conference. California Chapter of ASA and California Plant Health Association, Visalia, CA. (Received 2nd prize for graduate student).
13. **Cassel S., F.**, D. Goorahoo, and P. Yadavali. 2009. Enhancing calcium uptake in tomatoes grown in saline soils through fertilization and acidification. Agronomy Abstracts Annual Meetings, ASA-CSSA-SSSA, Madison, WI.
14. **Cassel S., F.** and D. Goorahoo. 2009. Electromagnetic surveys for soil salinity assessment and management. Workshop for JG Boswell delegates (October 13th). Claude Laval Water and Energy Technology Incubator, Fresno, CA.
15. Goorahoo, D., **F. Cassel S,** and S. Benes. 2009. Soil salinity characterization in the

Westside San Joaquin Valley, CA. Multi-State Salinity Coalition, Indian Wells, CA.

16. **Cassel S., F.**, D. Goorahoo, and D. Adhikari. 2009. Soil salinity mapping. Presentation to the Egyptian Irrigation Specialists delegation, UCD International Programs (August 18th). California Agriculture and Technology Institute, CSU Fresno.
17. **Cassel S, F.,** D. Goorahoo, and S. Benes. 2009. Knowing your soils – How salinity impacts irrigation decisions. Special Grower Education Event: Managing Irrigation in a Water-Short Year (April 22nd). Claude Laval Water & Energy Technology Incubator, Fresno, CA.
18. Goorahoo, D., **F. Cassel S,** and S. Benes. 2009. Managing soil salinity in the San Joaquin Valley (SJV). Presentation to the Iraqi delegation (April 9th). Claude Laval Water and Energy Technology Incubator, Fresno, CA.
19. Goorahoo, D., S. Benes, and **F. Cassel S**. 2009. Agriculture and soil salinity in the San Joaquin Valley (SJV), California. Presentation to the Iraqi delegation (April 9th). Claude Laval Water and Energy Technology Incubator, Fresno, CA.
20. **Cassel S., F.**, D. Goorahoo, and D. Adhikari. 2008. Soil salinity mapping. Presentation, to Australian delegation (May 9th). Claude Laval Water and Energy Technology Incubator, Fresno, CA.
21. **Cassel S., F.,** J. Tischer, D. Zoldoske, and E. Norum. 2007. Assessing potential seepage along canals and recharge basins with the electromagnetic technique. Proceedings, International Water Technology Conference, CSU Fresno. (CD)
22. **Cassel S., F**. and D. Goorahoo. 2007. Monitoring soil salinity in on-farm drainage management systems using the electromagnetic technique. Proceedings, International Water Technology Conference, CSU Fresno. (CD)
23. **Cassel S., F.** 2006. Evaluating seepage around water recharge basins: a 3D GIS approach. Presentation at GIS Day 2006, CSU Fresno. (Invited)
24. **Cassel S., F.** 2006. Site-specific seeding management to improve cotton yields in saline-affected soils. Presentation to Chinese delegation (November 16th), CIT-CSU Fresno.
25. **Cassel S., F**. and D. Zoldoske. 2006. Assessing canal seepage and soil salinity using the electromagnetic remote sensing technology. First International Conference on Sustainable Irrigation Management, Technologies and Policies, Bologna, Italy.
26. **Cassel S., F.** 2006. Electromagnetic mapping of salinity and boron for site-specific seeding management in cotton fields. Abstracts, World Congress of Soil Science, Philadelphia, PA. p. 252.
27. **Cassel S., F.** 2006. Use of electromagnetic remote sensing for precision agriculture in cotton systems. Presentation to Australian delegation, CIT-CSU Fresno.
28. **Cassel S., F.** 2006. Using Remote sensing techniques to evaluate effectiveness of drainage reuse systems in saline soils. Abstracts, Canadian Geophysical Union and Canadian Society of Soil Science Annual Meetings, Banff, Canada. p. 27.
29. **Cassel S., F.** 2006. Using remote sensing to determine soil salinity and boron levels in drainage reuse systems. Proceedings, 27th Annual Central California Research Symposium, Fresno, CA. p. 107.
30. **Cassel S., F.** 2006. Integrating remote sensing and GIS to assess salinity in drainage reuse systems. Abstracts, 12th Annual CalGIS Conference, Santa Barbara, CA. p. 16.
31. **Cassel S., F**. 2005. Mapping soil salinity in golf courses using a magnetic induction technique. Presentation at Silicon Valley User Group Meeting & GIS Day 2005, Santa Clara Valley Water District, San Jose, CA. (Invited)

32. **Cassel S., F.**, D. Adhikari, and D. Goorahoo. 2005. Salinity mapping of fields irrigated with winery effluents. Proceedings, Technical Conference, Irrigation Association, Tampa, FL.
33. **Cassel S., F.**, B. Taylor, and D. Zoldoske. 2004. Electromagnetic Sensing of Salinity and Boron for Predicting Variable Seeding Zones. Agronomy Abstracts, Annual Meetings, ASA-CSSA-SSSA, Madison, WI. (CD)
34. Horney, R., **F. Cassel S.**, B. Taylor, D. Munk, B. Roberts, R. Plant. 2004. Temporal evaluation of reclaiming salt-affected soil. Proceedings, 7th International Conference on Precision Agriculture and other Precision Resource Management, Minneapolis, MN. *In* D.J. Mulla, ed. Madison, Wisconsin: ASA-CSSA-SSSA (CD).
35. **Cassel S., F.** 2004. Use of Electromagnetic Technique for the Reclamation of Saline Soils. Abstracts, Eurosoil 2004, Freiburg, Germany. p. 129.
36. **Cassel S., F.**, D. Zoldoske, T. Jacobsen, E. Norum, and S. Mettler. 2004. Soil salinity surveys using EM technology. Presentations at workshops "Managing Agricultural Drainage Water". Five Points and Los Banos, CA.
37. **Cassel S., F**., J. Tischer, and D. Zoldoske. 2004. Canal seepage investigation using the electromagnetic technique. Presentation at Northern California Water Association manager meeting. Western Canal Water District, Nelson, CA.
38. **Cassel S., F.**, B. Taylor, B. Roberts, and D. Zoldoske. 2003. Site-specific salinity management for cotton production using remote sensing techniques. Agronomy Abstracts, Annual Meetings, ASA-CSSA-SSSA, Madison, WI. (CD)
39. **Cassel S., F.**, D. Zoldoske, E. Norum, and T. Jacobsen. 2003. Detecting canal seepage using the electromagnetic induction method. Proceedings, Technical Conference, Irrigation Association, San Diego, CA.
40. **Cassel S., F.** 2003 & 2002. Soil EC maps. Presentations at Precision Agriculture Field Day #2 & #1, Lemoore, CA.
41. **Cassel S., F**. 2003. Soil Salinity Mapping and Wastewater Application. Presentation at California Water Institute & Lawrence Berkeley National Laboratory Collaboration & Brainstorming Mini-Conference, Fresno, CA.
42. **Cassel S., F.** D. Zoldoske, T. Jacobsen, S. Mettler, and E. Norum. 2003. Using Electromagnetic Sensing Technique for Assessing Soil Salinity and Canal Seepage. Presentation to the Cochran delegation, CSU Fresno (invited)
43. **Cassel S., F.**, D. Zoldoske, T. Jacobsen, and E. Norum. 2002. Using Electromagnetic Sensing Technique for Assessing Soil Salinity and Canal Seepage. Presentation at New Trends in Water and Environmental Engineering for Safety and Life. Capri, Italy.
44. **Cassel S., F.**, D. Zoldoske, T. Jacobsen, and E. Norum. 2002. Use of electromagnetic survey to assess potential canal seepage. Proceedings, California Plant and Soil Conference. California Chapter of ASA and California Plant Health Association, Sacramento, CA. p.169.
45. **Cassel S., F.**, D. Zoldoske, T. Jacobsen, and E. Norum. 2002. Assessing Potential Canal Seepage with Electromagnetic Technique. Proceedings, 23rd Annual Central California Research Symposium, Fresno, CA. p. 89.
46. **Cassel S., F.**, D. Goorahoo, and S. Sharmasarkar. 2001. Electromagnetic assessment of soil salinity under integrated on-farm drainage management in the Westside San Joaquin Valley. Abstracts, International Union of Soil Science- Bouyoucous Conference SSSA - UC, USDA -ARS George E. Brown Jr. Salinity Laboratory, Riverside, CA. p.57.

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EDUCATION

Ph.D., University of Maryland, College Park (expected Spring 2015)

Dissertation: "Economics of Society: Essays on Health, Marriage and Child Adoption"
Committee: Roberton C. Williams III (Chair), Anna Alberini, Snaebjorn Gunnsteinsson

M.S., University of Arizona, Tucson, 2008
M.A., *Economics*, Jawaharlal Nehru University, New Delhi, 2003
B.Com., St. Joseph's College of Commerce, Bangalore, 2001

FIELDS OF INTEREST

Primary: Development Economics, Behavioral Economics
Secondary: Applied Microeconomics, Environmental and Resource Economics

RESEARCH EXPERIENCE

Jr. Research Specialist, University of California, Merced, August 2012 - present
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Research Assistant, University of Maryland, College Park, August 2008 - July 2010

Research Assistant, University of Arizona, Tucson, August 2006 - June 2008

Research Associate, The Energy and Resources Institute, India, 2003 - 2006

TEACHING

Instructor, Econ 100: Intermediate Microeconomic Theory, Summer 2014
University of California, Merced

Instructor, Econ 130L: Econometrics Lab, Fall 2013, Spring and Fall 2014
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Teaching Assistant, Econ 100: Intermediate Microeconomic Theory, Fall 2013 and Fall 2014
University of California, Merced

Teaching Assistant, AREC 620: Optimization (Ph.D. level), Fall 2010 and 2011
University of Maryland, College Park

Teaching Assistant, AREC 404: Production Economics, Fall 2006
University of Arizona, Tucson

PUBLISHED PAPERS

Frisvold, George, and Anand Murugesan (2013), "Use of Weather Information for Agricultural Decision Making," *Weather, Climate and Society*, 5, January Issue, 55-69

Murugesan, Anand, Vikram Dayal and Saurabh Chugh (2008), "An Empirical Study of Sanitation and Health in Rural Uttarakhand, India," *International Journal of Ecological Economics and Statistics*, Winter 2008, 91- 99

WORKING PAPERS

Murugesan, Anand, Tauhidur Rahman, and Vikram Dayal (2014), "Neighbors Can Make You Sick: Hygiene and Health," World Bank DEC Working Paper Series, WPS 84797, Washington DC

Das, Sanghamitra, Vikram Dayal, Anand Murugesan, R Uma, M Sehgal, and S K Chhabra (2009), "An Integrated Empirical Model of Health Effects of Air Pollution: the Case of Mining in Goa, India," IEG Discussion Paper Series No. 139/2009, New Delhi

WORK IN PROGRESS

Murugesan, Anand, and Robert Innes (2014), "Are We Supporting Our Orphans Enough? Economics of Child Adoptions from Foster Care," University of Maryland, College Park, July (Job Market Paper)

Murugesan, Anand (2014), "Betrothal Testing, Beliefs and Bad Behavior: Effect of Testing Rules on HIV Transmission," draft paper, University of Maryland, College Park, March

Murugesan, Anand (2014), "Effect of Restrictive Same-Sex Adoption Policies on Outcomes in U.S. Foster Care," draft paper, University of Maryland, College Park, July

Innes, Robert, and Anand Murugesan (2014), "Norms, Morality and Incentives: Experimental examination of Dishonest Behavior"

Murugesan, Anand (2014), "Mining Trucks for Cooking Choolahs? Unpacking the Trade-offs in Outdoor and Indoor Air Pollution," preliminary paper, University of Maryland, April

PRESENTATIONS

"Are we supporting our orphans enough? Economics of Child Adoptions from Foster Care," presented at economics department lunch seminar, University of California, Merced, November 6 2014

"Neighbors Can Make You Sick: Sanitation Externalities and Health," presented at the annual meeting of the Western Economic Association, Denver, June 2014

"Are we supporting our orphans enough? Analysis of factors that affect adoptions from U.S. foster care," presented at the Annual ASSA meeting, Philadelphia, January 2014

"Counting Apples with Oranges: Methodological Challenges of Inter-Disciplinary Research," American Association for Advancement of Sciences, February 2011

"Inter-linkages in Poverty, Hygiene and Health: Evidence from Rural Uttarakhand, India," presented at the annual meeting of the Western Economic Association International, Seattle, July 2007

AWARDS AND HONORS

Jacob K. Goldhaber Travel Award, University of Maryland's Graduate School, 2014

Best Student paper, awarded second place for "Betrothal Testing, Beliefs and Bad Behavior: Effect of Testing Rules on HIV Transmission," Institutional and Behavioral Economics Section, AAEA, 2013

Research Scholarship, Economics Department, School of Social Sciences, Humanities and Arts, University of California, Merced, 2012-13

Complex Systems Summer School 2011 scholarship, Santa Fe Institute, 2011

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Curriculum vitae

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Education

University of Southampton (UK), Dept. Botany, B.Sc. Special Honors Botany (1961)
University of Nottingham (UK), Dept. Agricultural Botany, M.Sc. Plant Physiology (1963)
University of Nottingham (UK), Dept. Agricultural Botany, Ph.D. Plant Physiology (1966)

Appointments

University of Nottingham (UK):

1965-66	Demonstrator, Department of Agricultural Botany

National Research Council, Ottawa (Canada):

1966-68	NRC Postdoctoral Fellow, Department of Plant Physiology

University of California, Berkeley (USA):

1968-72	Assistant Specialist, Department of Soils and Plant Nutrition
1971-72	Lecturer, Department of Soils and Plant Nutrition
1972-78	Assistant Professor, Department of Soils and Plant Nutrition
1978-84	Associate Professor, Department of Plant and Soil Biology
1984-89	Professor, Department of Plant and Soil Biology
1989-present	Professor, Department of Plant and Microbial Biology

Teaching activities

Undergraduate

Physiology and Biochemistry of Plants (PMB 135, 3 semester units)
Environmental Plant Biology (PMB 180, 2 semester units)

Graduate

Workshop on Teaching (PMB 300, 2 semester units)

Training of Ph.D. and Postdoctoral students

Total of 47 students, most at the postdoctoral level.

Research activities

My earlier research focused on the physiology and biochemistry of environmental stresses. Since 1990 my research has centered on phytoremediation, the use of plants to clean up contaminated soil and water. My research approach is multidisciplinary in that my laboratory conducts research in ecology, plant physiology and biochemistry, microbiology, and molecular biology. My major accomplishments include development of the use of constructed wetlands to remove selenium (Se) and toxic heavy metals from agricultural and industrial wastewater, as well as the development of genetically engineered plants for the phytoremediation of Se- or heavy metal-contaminated soils. We were the first to demonstrate the successful use of transgenic plants for phytoremediation under field conditions [*Environmental Science & Technology*, 39:1771-1777 (2004); *Environmental Science & Technology*, 41: 599-605 (2007)].

Patents

Terry, N., Pilon-Smits, E.A.H., Zhu, Y.L., "Heavy metal phytoremediation" US Patent 6576816. 10 June 2003.
Terry, N., Pilon-Smits, E.A.H., de Souza, M., "Trace element phytoremediation" US Patent 6974896. 13 Dec. 2005.
Terry, N., Pilon-Smits, E.A.H., Zhu, Y.L., "Heavy metal phytoremediation" US Patent 7034202. 25 Apr. 2006.

Some recent publications **(total number published = 262)**

Huang, J. C., E. Passeport, N. Terry, 2012. Development of a constructed wetland water treatment system for selenium removal: use of mesocosms to evaluate design parameters. Environmental Science and Technology, 46: 12021-29

Verce, M.F, A. R. Stiles, K.C. Chong., N. Terry, 2012. Isolation of an extremely boron-tolerant strain of *Bacillus firmus.* Canadian Journal of Microbiology, 58(6): 811-814.

Huang, J. C., E. Passeport, N. Terry. 2012. Development of a constructed wetland water treatment system for selenium removal: use of mesocosms to evaluate design parameters. Environmental Science and Technology, 46: 12021-29

Stiles AR, Liu C, Kayama Y, Wong J, Doner H, Funston R, Terry N. 2011. Evaluation of the boron tolerant grass, Puccinellia distans, as an initial vegetative cover for the phytorestoration of a boron-contaminated mining site in Southern California. Environmental Science and Technology, 45: 8922-7.

Lin, Z.Q., N. Terry, S. Gao, S. Mohamed, Z.H. Ye. 2010. Vegetation changes and partitioning of selenium in 4-year-old constructed wetlands treating agricultural drainage. International Journal of Phytoremediation, 12: 255-267.

Stiles, A.R., Bautista, D., Atalay, E., Babaoğlu, M., Terry N., 2010. Mechanisms of Boron Tolerance and Accumulation in Plants: A Physiological Comparison of the Extremely Boron-Tolerant Plant Species, *Puccinellia distans*, with the Moderately Boron-Tolerant *Gypsophila arrostil*. Environmental Science and Technology, 44: 7089- 7095.

Z.-Q. Lin, N. Terry, S. Gao, S. Mohamed, Z.H. Ye. 2009. Vegetation changes and partitioning of selenium in 4-year-old constructed wetlands treating agricultural drainage. International Journal of Phytoremediation, 12(3): 255-267.

Reisinger S, Schiavon M, Terry N, Pilon-Smits EAH. 2008. Heavy metal tolerance and accumulation in Indian mustard (Brassica juncea L.) overexpressing bacterial g- glutamylcysteine synthetase or glutathione synthetase. International Journal of Phytoremediation, 10: 440-454

Mohamed, H., Ruiz, O., Terry N., Daniell, H., 2007. Phytoremediation of mercury and organomercurials in chloroplast transgenic plants: Enhanced root uptake, translocation to shoots and volatilization. Environmental Science & Technology 41(24): 8429-8446.

Kassis, E.E., Cathala, N., Rouached, H., Fourcroy, P., Berthomieu, P., Terry, N., Davidian, J-C., 2007. Characterization of a selenate-resistant Arabidopsis thaliana mutant: root growth as a potential target for selenate toxicity. Plant Physiology, 143:1231-1241.

Lin, Z-Q., Mohamed, H., Ye, Z.H., Terry, N., 2007. Phytorestoration of metal-contaminated industrial wasteland: A greenhouse feasibility study. In: D. Sarkar, R. Datta, and R. Hannigan (eds.), Concepts and Applications in Environmental Geochemistry. Elsevier, Amsterdam, The Netherlands. pp. 487-501.

Kubachka, K.M., Meija, J., LeDuc, D.L., Terry, N., Caruso, J.A., 2007. Selenium volatiles as proxy to the metabolic pathways of selenium in genetically modified *Brassica juncea*. Environmental Science and Technology, 41:1863-1869.

Bañuelos, G., LeDuc, D., Pilon-Smits, E.A.H., Terry, N., 2007. Transgenic indian mustard overexpressing selenocysteine lyase or selenocyteine methyltransferase exhibit enhanced potential for selenium phytoremediation under field conditions. Environmental Science and Technology, 41:599-605.

Navaza, A.P., Montes-Bayon, M., LeDuc, D.L., Terry, N., Sanz-Medel, A., 2006. Study of phytochelatins and other related thiols as complexing biomolecules of As and Cd in wild type and genetically modified *Brassica juncea* plants. Journal of Mass Spectrometry, 41:323-331.

Lindblom, S. D., Abdel-Ghany, S. E., Hanson, B. R., Hwang, S., Terry, N., Pilon-Smits, E.A.H., 2006. Constitutive expression of a high-affinity sulfate transporter in *Brassica juncea* affects metal tolerance and accumulation. Journal of Environmental Quality, 35:726-733.

Terry N., 2005. Phytoremediation of toxic trace elements in soil and water. Journal of Industrial Microbiology and Biotechnology, 32:514-520.

Bañuelos, G., Terry, N., LeDuc, D., Pilon-Smits, E.A.H., Mackey, B., 2004. Field trial of transgenic indian mustard plants shows enhanced phytoremediation of selenium-contaminated soil. Environmental Science and Technology, 39:1771-1777.

Wangeline, A. L., Burkhead, J. L., Hale, K. L., Lindblom, S-D., Terry, N., Pilon, M., Pilon-Smits, E. A. H., 2004. Overexpression of ATP sulfurylase in *Brassica juncea*: Effects on tolerance and accumulation of twelve metals. Journal of Environmental Quality, 33: 54-60.

LeDuc, D. L., Tarun, A.S., Montes-Bayón, M., Meija, J., AbdelSamie, M., Wu, C.P., Malit, M.F., Chang, C.-Y., Tagmount, A., de Souza, M., Neuhierl, B., Böck, A., Caruso, J., Terry, N., 2004. Overexpression of selenocysteine methyltransferase in *Arabidopsis thaliana* and *Brassica juncea* increases selenium tolerance and accumulation. Plant Physiology, 135:377-383.

Grant, T.D., Montes-Bayon, M., LeDuc, D., Fricke, M.W., Terry N., Caruso, J.A., 2004. Identification and characterization of Se-methyl selenomethionine in *Brassica juncea* roots. Journal of Chromatography A., 1026:159-166.

Book: Terry, N. G. S. Bañuelos (eds.). 2000. Phytoremediation of Trace Elements. Lewis Publishers, Boca Raton. 389 pages.

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Education

High school
Mclane High School Fresno 1993

Professional experience

Field technician, Irrigation systems since 2013
Water Management Research Laboratory
Supervisor: Dr. Gary Banuelos and Dr. David Zolodske
USDA-ARS Parlier, CA

Field technician, Grape breeding 2008-2013
Crop, Diseases, Pests and Genetics Laboratory
Supervisor: Dr. David Ramming
USDA-ARS Parlier, CA

Farmer and grower 1993-2008
Self-owned 10 acres ranch in Reedley CA

Technical skills

Machine operator: tractors, back whole, bob cat, and trencher
General labor: field plot maintenance, pruning, weed badging, weed control
Field plot preparation: tillage, irrigation system installation, planting

Justin E. King

Curriculum Vitae

Basic Information

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Interests

Computational Medicine, Cerebrovascular Physiology, Cardiovascular Diseases, Platelet Biology, Chronic Pain, Toxicology, Emergency Medicine

Education

B.A. Chemistry	California State University: Fresno	expected 2015

Professional Experience

2013 -	Biological Laboratory Technician	USDA-ARS
2011 – '13	Plumbing and Electrical Assistant	Orchard Supply Hardware
2010 -	Tutor: Chemistry and Biology	CSU, Fresno

Presentations

2014	CSU, Fresno Chemistry Department Seminar: *Bcl-2 family proteins: roles in apoptosis and carbohydrate metabolism*

Technical Skills

Business	Conflict Resolution, Scheduling
Biology	Cell Culture, RT-PCR
Biochemistry	Western Blotting, Gel Electrophoresis, Assays
Chemistry	NMR, IR, HPLC, ICP-MS, ICP-OES
Medical	Emergency Medical Technician *license pending*
Platforms	Windows, Apple, Linux, iOS, Android
Programs	Sigma Plot (moderate), SAS (basic), RStudio (basic)

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Education:

California State University, Fresno *Fresno, CA*
Master of Science, Plant Science *Expected Date, May 2016*
California State University, Fresno *Fresno, CA*
Baccalaureate of Science, Plant Science/Crop Production *Graduated May 2014*
Hoover High School *Fresno, CA*
Diploma *Graduated May 2009*

Research and Work Experience:

Student Research Assistant *July 2011- Present*
Drs. Dave Goorahoo, Florence Cassel Sharma "Center Irrigation Technology" *Fresno, CA*

- Salinity Mapping using EM38 instrument and software.
- Research fields management, Fields and data collection, Fields scout and operator.
- Laboratory Analyses of soil-plant-water samples.
- Treatment applications, Irrigation management, Irrigation design.

Office Assistant *August 2008-May 2009*
Yang Appraisal Services *Fresno, CA*

- Responsible for the daily office operations and correspondences, Providing customer services to clients.
- Promote the Yang Appraisal Services to the community through radio, flyers, and mailing advertisements.

Membership in Academia & Professional Societies:

*Sigma Alpha Lamba *2014*
*Agronomy Society of America *2012*
*Crop Science Society of America *2012*
*Soil Science Society of America *2012*
*Students of Agronomy, Soils, and Environmental Science *2012*
*Ronald McNair Scholar, Fresno State *2012*
*Golden Key Scholar, Fresno State *2011*
*The National Society of Collegiate Scholar, Fresno State *2011*
*Plant Science Club Member, Fresno State *2010*
*Educational Opportunity Program (EOP) Student, Fresno State *2009*

Publications and Presentations

1. Goorahoo, D., F. Cassel S., **T. Thao**, F. Melton, and L. Johnson. 2014. An Integrated Lysimeter and Satellite Imagery Approach for Estimating Crop Evapotranspiration. AGU Fall Meeting, San Francisco, CA.

2. Cassel S., F., **T. Thao,** and D. Goorahoo. 2014. Updated Evapotranspiration Estimates and Crop Coefficients to improve Irrigation Scheduling in Sub-Surface Drip Irrigated Vegetable Systems. Irrigation Association Conference, Phoenix, AZ.

3. **Thao, T.,** F. Cassel S., Dave G., and C. Cochran. 2014. New Evapotranspiration Estimates and Crop Coefficients for Optimizing Sub-Surface Drip Irrigation Scheduling. ASA-CSSA-SSSA Conference, Long Beach, CA, and CSU, Agricultural Research Institute, Pomona, CA.

4. Dehghanmanshadi, B., F. Cassel S. , D. Goorahoo, and **T. Thao**. 2013. Optimizing Water Use Efficiency of Tomato Under Subsurface Irrigation with ET model. Soil and Water Conservation Society, Reno, NV; CSU-Water Resources and Policy Initiative, Long Beach, CA; Water Technology Conference, Clovis, CA.

5. Wang, M., **T. Thao**, D. Goorahoo, and D. Bacon. 2012. Effect of Organic and UAN-32 Fertilization on Bok Choy and Soil Properties. California Chapter-American Society of Agronomy – Plant and Soil Conference, Visalia, CA.

6. **Thao, T.,** NS D. Goorahoo. 2012. Effect of Organic and UAN-32 Fertilization on Bok Choy Yield and Soil Properties. 33rd Annual Central California Research Symposium, Fresno CA and 4th Annual Water Resources and Policy Initiatives, Sacramento, CA

Awards and Scholarships:

1. Irrigation E3 Leaner, Irrigation Association, 2014
2. Assemblyman Jim Patterson's Agriculture Science Students of the Year Award, 2014
3. Plant Science Undergraduate Student Achievement Award, 2014
4. Standard Bearer, Jordan School of Agriculture and Technology, 2014
5. Dean's Medalist Nominee, Department of Plant Science, 2014
6. National Student Recognition Award, 2014 ASA-CSSA-SSSA
7. Golden Opportunity Scholar, 2013 ASA-CSSA-SSSA
8. Jensen Scholarship, 2013
9. Valley Grower Local Sunweet Grant, 2013
10. Ag One-Dr Marinus Van Elswyk Grant, 2013
11. Ag One-Dick Markarian Grant, 2012
12. CA Cotton Alliance Scholarship, 2012
13. Ronald McNair Research Grant, 2012
14. Undergraduate Research Grant, 2011
15. General Dillingham Scholarship, 2011
16. CAST Scholarship, 2011
17. EOP Summer Bridge-Counselor & Peer Mentor Award, 2009
18. EOP Summer Bridge- Peer Mentor Award, 2009

Skills:

*Fluent in **English** and **Hmong** (Interpreter/Translator)
*Proficient in Microsoft Windows
***Microsoft Office:** Word, Excel, PowerPoint, and SPSS

Appendix B

Copy of manuscript (Centofanti and Banuelos, 2014) is enclosed in this section. The manuscript has been submitted to Journal of Environmental Management and it is currently under review.

Evaluation of the halophyte *Salsola soda* as an alternative crop for saline soils high in selenium and boron

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Abstract

Urbanization, industrial development, and intensive agriculture have caused soil contamination and land degradation in many areas of the world. Salinization is one important factor contributing to land degradation and it affects agricultural production and environmental quality. When salinization is combined with soil pollution by trace elements, as it occurs in many arid and semi-arid regions around the world, strategies to phyto-manage pollution and sustain crop production need to be implemented. In this study we present the case of saline soils in the West side of Central California which contain naturally-occurring selenium (Se), boron (B), and other salts, such as NaCl, $CaCl_2$, Na_2SO_4, and Na_2SeO_4.

To sustain crop production on Se- and B-laden arid saline soils, we investigated the potential of the halophyte "agretti" (*Salsola soda L.*) as an alternative crop. The aim of our greenhouse study was to examine adaptability, B tolerance, and Se accumulation by *S. soda* grown on soils collected from a typical saline-laden field site located on the West side of the San Joaquin Valley (SJV).

Our results showed that *S. soda* tolerates the saline (EC ~ 10 dS m^{-1}) and B-laden soils (10 mg B L^{-1}) of the SJV even with the additional irrigation of saline and B rich water (EC~ 3 dS m^{-1} and 4 mg B L^{-1}). Under these growing conditions, the plant can accumulate high concentrations of Na (80 g Na kg^{-1} DW), B (100 mg B kg^{-1} DW), and Se (3-4 mg Se kg^{-1} DW) without showing any toxicity symptoms. Hence, *S. soda* showed promising potential as a plant species that can be grown in B-laden saline soils and accumulate and potentially manage excessive soluble Se and B in soil.

Keywords

Salinity, halophyte, *Salsola soda*, boron, selenium, alternative crops

1. Introduction

Loss of productive land due to abiotic stresses (i.e. drought, increased salinity, and soil pollution) is posing major challenges to provision of nutritious and safe food, sustainability of agriculture, and conservation of agro-ecosystems and environmental quality. Salinization combined with recurrent droughts and higher uncertainty in climate stability represents a serious threat to agricultural production in many regions around the globe (United States, China, Australia, Bangladesh, India, etc.). Salinization combined with occurrence of trace elements, as in salt marshes and in arid-saline areas where the soil is naturally rich in trace elements, requires implementation of management strategies for sustainable crop production and protection of water quality.

For example, farming traditional and alternative crops in saline, arid and poor quality soils may be considered one of the potential strategies to sustain the current and future global food system. One possible strategy to manage high levels of soluble trace elements is to firstly identify drought and salt tolerant crops that can survive such poor growing conditions, and then use the plants to extract soluble trace elements (i.e. Se and B) from the soils (Bañuelos et al., 1996).

Many soils in the Western United States, e.g. West side of central California, are derived from Cretaceous shale rock and contain naturally-occurring selenium (Se), boron (B), and other salts, such as sodium chloride (NaCl), calcium chloride ($CaCl_2$), sodium sulfate (Na_2SO_4), and sodium selenate (Na_2SeO_4) (Schoups et al., 2005). In the West side of central California excessive accumulation of Se and B in the groundwater was caused by a combination of geology, salinity, intensive irrigation practices, and lack of tile drainage system (Presser and Schwarzbach, 2008). In the past, inefficient irrigation delivery systems contributed to

solubilization and redistribution of those natural-occurring trace elements and other salts within the soil profile. Excessive concentrations of soluble trace elements, i.e., B, Se, have proven to be damaging to their surrounding eco-environment, including both plants and biological systems (Ohlendorf et al., 1986). Other similar areas within the Western USA, i.e., Colorado, Wyoming, Nevada, and Montana, were also concerned about similar ecological disasters occurring within their respective susceptible regions, due to high levels of soluble B, Se, and other trace elements resent in their soils. In the west side of central California, indian mustard (*Brassica juncea*) and canola (*Brassica napus* L.) are two of the most common plants species utilized for phyto-managing B- and Se-laden saline soils (Bañuelos, 2001). Plant species used for the phyto-management of soluble ions in arid saline soils must tolerate high levels of salinity and B and accumulate naturally occurring Se from the soil. In regard to salt and B tolerance, salt-tolerant plants (halophytes) may satisfy this requirement and thus making halophytes optimal candidates for the phyto-management of soluble ions in trace element laden saline soils.

Salsola Soda L., more commonly known as 'agretti' (Fig. 1), is a halophyte native to the Mediterranean basin. It is a relatively small plant that grows to about 0.7 meters on average in coastal regions and can be irrigated with salt water. Throughout history, the plant was a very important source of soda ash, as people would extract the ashes from *S. soda*. The plant is no longer grown for the use of its soda ash but rather it is farmed as a vegetable. In folk medicine, *Salsola* species are traditionally used for the treatment of hypertension, constipation and inflammation (Tundis et al., 2009). In this regard, alkaloid extracts from *Salsola* species have been evaluated for the treatment of Alzheimer's disease (Tundis et al., 2009).

Figure 1. Wild *S. soda* growing on the coast near the sea water (left) and cultivated *S. soda* known as 'agretti' vegetable (right).

S. soda has been studied by Colla et al. (2006) and Graifenberg et al. (2003) as a "biodesalinating companion plant" to tomatoes and peppers in saline soils in central Italy. The authors showed that pepper and tomatoes respectively grown together with *S. soda* had a higher yield than if grown alone as monocrop. They attributed the higher yields to the ability of the halophyte 'agretti' to accumulate Na and reduce sodium's impact on pepper and tomatoes.

S. soda is a halophyte that is cultivated in Italy where it is consumed as a vegetable and it is offered in gourmet restaurants in Europe and America. The plant was recently documented as one of the endemic species in alkali grasslands typical of Central and Eastern Europe such as those in the Carpathian-basin (Török et al., 2012). Recent studies have shown the potential use of *S. soda* for the phytostabilization of polluted areas, as it can accumulate moderate levels of trace metals (Milić et al., 2012, Lorestani et al., 2011).

S. soda's ability to grow on typical saline and B and Se-laden soils of the western United States has never been studied before. This study evaluates the potential of growing *S. soda* in B- and Se- laden soils of the west side of central California as both an alternative food crop and as potential species for phyto-management of Se and B in saline soils.

The aim of our study was to evaluate adaptability, salt and B tolerance, and Se accumulation by *S. soda* grown on typical unproductive saline soils collected from the west side of central California (Five Points, CA). We hypothesized the following: a) *S. soda* will be able to tolerate B and the salts present in the soil and safely accumulate potentially plant toxic ions, i.e., Na, Cl, and B, and b) *S. soda* will accumulate Se in the above ground biomass.

2. Materials and methods

2.1 Greenhouse Pot Experiment

Seeds of *S. soda* were purchased from the commercial retailer 'Seeds from Italy' (Lawrence, KS). The seeds were pre-germinated on potting soil and in plastic flats for 18 days. The germination potential of the seeds was about 65%. Seeds were watered daily twice a day with low saline water (electrical conductivity (EC) < 0.5 dS m^{-1}). The experiment was carried out under greenhouse conditions at SJV Agricultural Research Center in Parlier, CA. Greenhouse conditions were as follows: day/night temperatures 28/20°C, 16 h photoperiod, 40-50% relative humidity of ambient air, and an average daily 200 µmol photons m^{-2} s^{-1} minimum light intensity. After 18 days, seedlings were transplanted into 2 kg pots filled with two types of typical west (saline) and east side (non-saline) soils of Central California. The saline soils consisted of an Oxalis silty clay loam (fine montmorillonitic, thermic Pachic Haploxeral with a well-developed salinity profile) collected at Red Rock Ranch (Five Points, CA) , while the non-saline soil (designated as control) consisted of a Hanford sandy loam (coarse-loamy, mixed superactive, nonacid, thermic Typic Xerothents) soil collected at the SJV Agricultural Research Center in Parlier, CA. Chemical characteristics of the two soils (saline and control) are described in Table 1 and in Bañuelos (2002) and in Bañuelos and Lin (2010), respectively.

Table 1. Description of treatments used in the study and selected chemical characteristics of the soils used. Data represent average of three replicates and standard error in brackets.

Treatment name	Soil type	Quality of Irrigation water	Soil EC (dS m^{-1})[a]	pH	Water extractable boron[b] (mg L^{-1})	Water extractable selenium[b] (mg L^{-1})	Water extractable sodium[b] (mg L^{-1})
T1	Oxalis silty clay loam	Deionized water	10.2 (0.6)	8.02 (0.06)	10.45 (0.25)	0.2 (0.003)	1469 (0.2)
T2	Oxalis silty clay loam	Saline solution[c]	10.2 (0.6)	8.02 (0.06)	10.45 (0.25)	0.2 (0.003)	1469 (0.2)
T3	Hanford sandy loam	Deionized water	2.3 (0.5)	7.68 (0.03)	0.12 (0.004)	0.002 (0.000)	96.7 (9.4)
T4	Hanford sandy loam	Saline solution[c]	2.3 (0.5)	7.68 (0.03)	0.12 (0.004)	0.002 (0.000)	96.7 (9.4)

[a] values of electrical conductivity (EC) at the start of the experiment

[b] concentrations of B, Se, and Na at the start of the experiment

[c]applied 2 weeks after transplanting; the saline solution had an electrical conductivity of 3.2 dS m^{-1} comprised of $CaCl_2$, NaCl, and Na_2SO_4 and 0.250 mg Se L^{-1} as Na_2O_4Se and 4 mg B L^{-1} as H_3BO_3

Treatments on saline and control soils were as follows: treatment 1 (T1): soil from Red Rock Ranch with EC of 10 dS m^{-1} and water soluble B of 10 mg L^{-1}; treatment 2 (T2): soil from Red Rock Ranch with EC 10 dS m^{-1} and water soluble B of 10 mg L^{-1}+ irrigation with saline solution (described below and in Table 1); treatment 3 (T3): control soil from SJV Agricultural Research Center with EC of 2.3 dS m^{-1} and water soluble B of 0.12 mg L^{-1}; and treatment 4 (T4): control soil from SJV Agricultural Research Center with with EC of 2.3 dS m^{-1} and water soluble B of 0.12 mg L^{-1} + irrigation with saline solution (described below and in Table 1). Five replications per treatment were used and the pots were placed in the greenhouse in a complete randomized block design.

For each treatment, three pots without plants were also added and treated similarly as the planted pots within each treatment. Soil samples were taken weekly with a micro-auger from the unplanted pots in three random locations in the 5 cm layer within each pot. Those unplanted pots were used to monitor for changes in soil EC and pH on a weekly basis throughout the experiment.

For the first week of the experiment, all pots were watered twice a day with a total 60 mL per day of low salinity water (EC < 0.5 dS m^{-1}). The amount of water applied was reduced to a total 30 mL a day in the second week of the experiment to maintain soil moisture at about 15% and to simulate a moderate water stress for each treatment. Irrigation water was added to drainage saucers to avoid leaching and to assure homogenous wetness of the soil. Two weeks after transplanting, treatments 2 and 4 received saline solution as source of irrigation water (Table 1). The saline solution added as irrigation had electrical conductivity of 3.2 dS m^{-1}, which was comprised of $CaCl_2$, NaCl, and Na_2SO_4 salts, 0.250 mg Se L^{-1} as Na_2O_4Se and 4 mg B L^{-1} as H_3BO_3. Salts and B composition of saline solution represents a typical lower quality groundwater

oftentimes present in the west side of Central California. The saline solution was applied three days a week for three weeks, while 30 mL of low salinity water (EC < 0.5 dS m^{-1}) were applied to each pot on the other 4 days of the week. Plants were not fertilized.

Shoot height was recorded weekly by measuring the length of shoot from top to 0.5 cm from soil surface. Plants were monitored weekly for insect infestation and for the appearance of any toxicity and/or deficiency symptoms.

2.2 Harvest

All plants were harvested 30 days after transplanting, irrespective of treatment. Shoots were cut 1 cm above soil surface, weighed, washed in deionized water, and pat dry prior to drying in the oven at 55 °C for at least five days. The soil from each pot was emptied out onto a dry surface, mixed thoroughly and sampled randomly to collect approximately two bags from each pot, each containing 150 g of moist soil for analysis of: 1) total and water extractable mineral elements, and 2) pH and EC. Prior to analysis, soil samples were oven dried at 55 °C for at least five days. All soils and shoot samples were weighed and then ground in a stainless steel Wiley mill equipped with a 0.83 mm screen before being acid digested for mineral analysis (described below). Plant roots were not collected because the root system is very fine and it was very difficult to wash the soil particles off the roots without breaking them.

2.3 Water soluble mineral elements, chloride, electrical conductivity, and pH

Water soluble elements concentrations (expressed as mg L^{-1}), chloride, salinity [electrical conductivity (EC); dS m^{-1}] and pH were determined in a 1:1 soil-water extract. Water soluble Se was analyzed using an Agilent ICP-MS (Santa Clara, CA) and other soluble ions were measured using Varian Vista ICP-OES (Palo Alto, CA) after preparing the samples, as described by Bañuelos and Meek (1990). Soil EC was measured at room temperature using an Orion Model

150 Conductivity Meter (Thermo Scientific, Waltham, USA), chloride analysis was performed at room temperature with a Mettler Toledo Titrator (Mettler Toledo, Columbus, OH, USA), and pH was determined at room temperature using an Orion 420A pH meter (Thermo Scientific, Waltham, USA).

2.4 Total mineral elements

A standard procedure was used to determine the mineral element concentrations in *S. soda* shoot and soil samples (Bañuelos and Lin, 2010). Plant tissues were wet digested with HNO_3-H_2O_2-HCl, as described by Bañuelos and Akohoue (1994). NIST coal fly ash (SRM 1633; Se content of 10.3 ± 0.6 mg kg^{-1}, with a recovery of 93%) and NIST wheat flour (SRM 1567; Se content of 1.1 ±0.2 mg kg^{-1}, with a recovery of 94%) were used as an external quality control standard for the soil and plant material, respectively. Selenium and other elements were analyzed by an inductively-coupled plasma optical emission spectrometer (Agilent 7500cx, Santa Clara, USA) according to Agilent manufacture protocol.

2.5 Statistical analysis

All data were analyzed using the SAS package (Institute, 1989). The Proc Mixed procedure was used for analysis of variance to determine difference between treatments. Significance was set at the 5% level.

3. Results and discussion

Concentrations of total and water soluble As, B, Ca, Cl, Mg, Na, S, and Se were higher in the saline soil (T1and T2) than in control soil (T3 and T4) (Table 2 and 3) at harvest, while concentrations of K, P, and Zn were higher in control soils compared to saline soils at harvest (Table 2 and 3), and Fe, Mn, and Cu were similar in both saline and control soils. Water extractable B, Na and Se concentrations were significantly higher at harvest in control soils (T4)

after irrigation with saline solution compared to the control soil irrigated with low saline water (T3) (Table 2 and 3). In the saline soils (T1 and T2), values of soil pH increased over time (Fig. 2) after the second week of the experiment and leveled out after the third week to the end of the experiment. In the control soils (T3 and T4), pH values decreased slightly during the first week of the experiment but they showed an overall stable pattern during the experiment without any significant change from time 0 to harvest (Fig. 2). In both saline soil (T1 and T2) and control soil (T3 and T4), pH values were higher in planted pots at harvest than before planting (time 0, Fig. 2) but not significantly higher than the pH values in the unplanted pots at the end of the experiment. Similarly, soil EC at harvest was similar to soil EC before planting (time 0) in both planted and unplanted pots (data not shown) in all treatments.

Table 2. Water extractable (g or mg L^{-1}) and total (g or mg kg^{-1}) concentrations of mineral elements (Ca, Fe, K, Mg, Mn, Na, P, and S) in soil at harvest. Values represent average of 5 replicates and standard error (SE) in brackets. Stars (*) indicate statistical significance at P≤0.05.

Element	T1[a]	T2[a]	T3[a]	T4[a]
Ca (g L^{-1})	0.89 (0.01)	0.53 (0.00)	0.06 (0.00)	0.07 (0.00)
Ca (g kg^{-1})	16.26 (0.25)	17.37 (0.46)	4.05 (0.12)	3.87 (0.11)
Fe (mg L^{-1})	0.41 (0.01)	0.41 (0.01)	0.90 (0.11)	0.45 (0.02)
Fe (g kg^{-1})	20.83 (0.21)	21.66 (0.25)	18.51 (0.32)	18.69 (0.72)
K (mg L^{-1})	41.53 (9.77)	43.31 (7.62)	192.56 (7.95)	189.69 (19.14)
K (g kg^{-1})	2.83 (0.07)	2.76 (0.1)	3.55 (0.04)	3.71 (0.1)
Mg (mg L^{-1})	92.98 (3.33)	74.88 (2.21)	19.99 (1.87)	21.88 (1.06)
Mg (g kg^{-1})	11.94 (0.1)	12.03 (0.22)	3.74 (0.04)	3.84 (0.07)
Mn (mg L^{-1})	0.03 (0.01)	0.02 (0.00)	0.09 (0.02)	0.10 (0.02)
Mn (g kg-1)	0.27 (0.00)	0.30 (0.00)	0.27 (0.00)	0.28 (0.00)
Na (g L^{-1})	1.47 (0.09)	1.41 (0.05)	0.02 (0.00)	0.04* (0.00)
Na (g kg^{-1})	2.94 (0.11)	2.64 (0.88)	0.17 (0.04)	0.16 (0.00)
P (mg L^{-1})	0.16 (0.09)	0.02 (0.02)	9.76 (1.66)	6.96 (0.43)
P (g kg^{-1})	0.76 (0.03)	0.64 (0.04)	1.68 (0.05)	1.33 (0.31)
S (g L^{-1})	1.57 (0.13)	1.06 (0.02)	0.04 (0.00)	0.05 (0.01)
S (g kg^{-1})	6.10 (0.11)	5.99 (0.25)	0.17 (0.02)	0.16 (0.01)

[a]See Table 1 for description of treatments.
* T4 statistically different (P≤0.05) than T3, no statistical difference was observed between T1 and T2 for the same element.

Table 3. Water extractable (g or mg L^{-1}) and total (g or mg kg^{-1}) concentrations of mineral elements (As, B, Cl, Cu, Se, and Zn) in soil at harvest. Values represent average of 5 replicates and standard error (SE) in brackets. Stars (*) indicate statistical significance at $P \leq 0.05$.

Element	T1[a]	T2[a]	T3[a]	T4[a]
As (mg L^{-1})	0.01 (0.00)	0.01 (0.00)	0.03 (0.00)	0.02 (0.00)
As (mg kg^{-1})	8.44 (0.08)	8.91 (0.17)	4.59 (0.14)	4.79 (0.17)
B (mg L^{-1})	13.48 (1.06)	9.87 (0.14)	0.05 (0.00)	0.13*(0.02)
B (mg kg^{-1})	66.05 (1.8)	69.78 (1.87)	3.40 (0.07)	2.37 (0.2)
Cl (g L^{-1})	1.20 (0.16)	1.10 (0.12)	0.45 (0.01)	0.45 (0.03)
Cu (mg L^{-1})	0.04 (0.00)	0.04 (0.01)	0.07 (0.01)	0.05 (0.00)
Cu (mg kg^{-1})	23.09 (0.37)	24.99 (0.49)	28.09 (0.27)	31.76 (0.85)
Se (mg L^{-1})	0.22 (0.02)	0.22 (0.02)	0.00 (0.00)	0.02*(0.00)
Se (mg kg^{-1})	2.76 (0.08)	2.69 (0.09)	0.10 (0.01)	0.10 (0.00)
Zn (mg L^{-1})	0.00 (0.00)	0.01 (0.01)	0.04 (0.02)	0.05 (0.02)
Zn (mg kg^{-1})	80.91 (0.68)	83.80 (1.6)	111.06 (4.34)	122.17 (9.85)

[a]See Table 1 for description of treatments.
* T4 statistically different ($P \leq 0.05$) than T3, no statistical difference was observed between T1 and T2 for the same element.

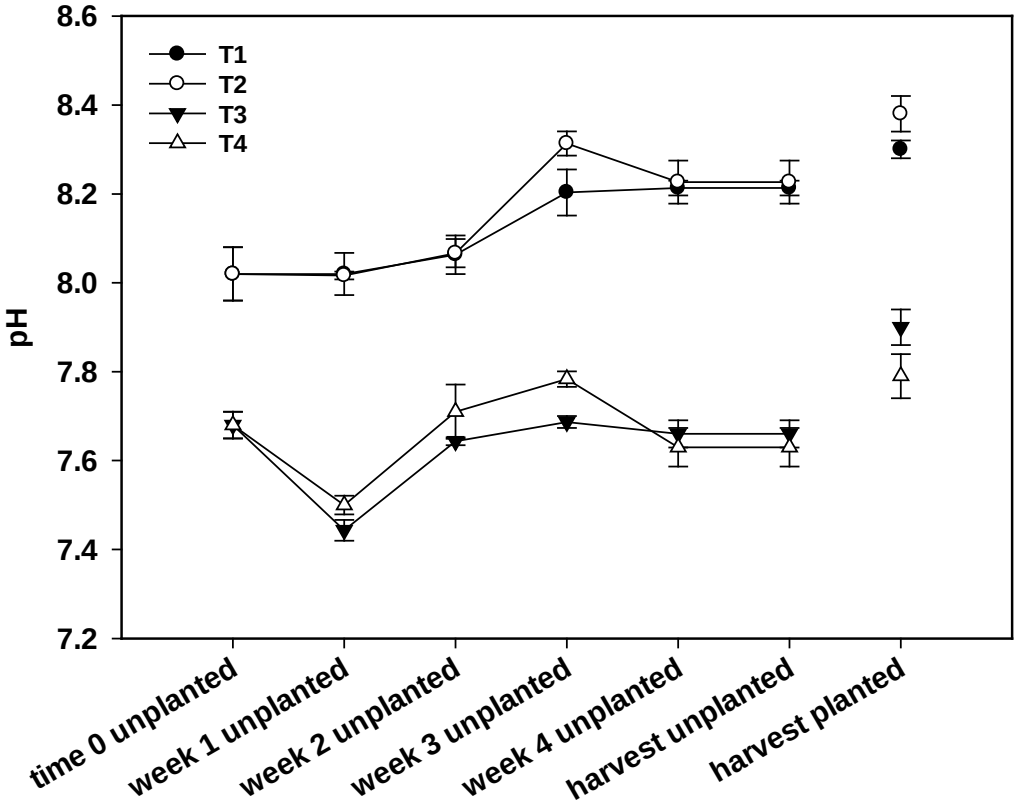
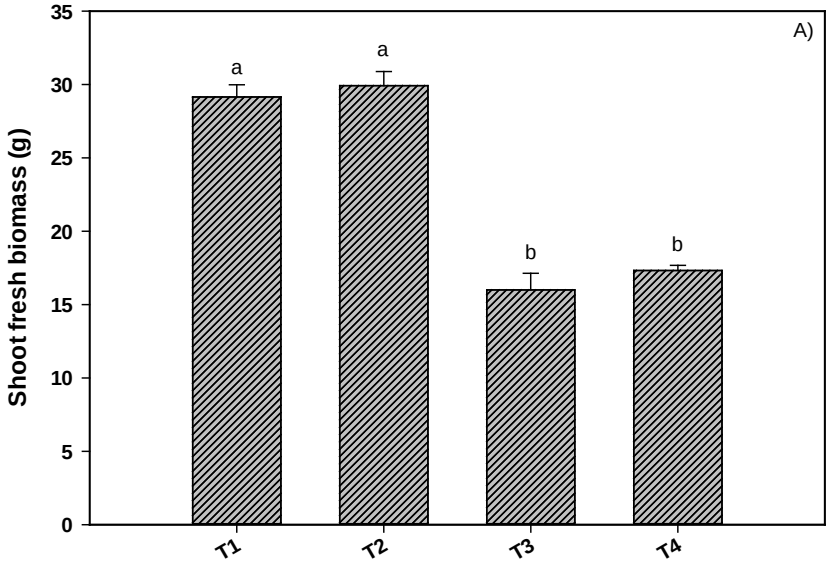


Figure 2. Soil pH measured at different times during the duration of the experiment in unplanted pots and at harvest in planted pots (harvest planted). Values represent average of five replicates and error bars represent SE. (T1: soil with EC of 10 dS m^{-1}, T2: soil with EC 10 dS m^{-1} + saline solution, T3: control soil, and T4: control soil + saline solution; see Table 1).

Irrespective of treatment, the plants were healthy throughout the experiment and they did not show any visual deficiency and toxicity symptoms despite receiving no fertilizer for 30 days. *S. soda* showed significantly higher shoot biomass, both fresh and dry, when grown on saline soil (T1 and T2) relative to control soil (T3 and T4) (Fig. 3). This observation indicates that *S. soda*, as halophyte, may require or utilize salts to thrive and produce higher biomass. *S. soda* is a succulent and therefore the difference between fresh and dry weight biomass was large (Fig. 3).



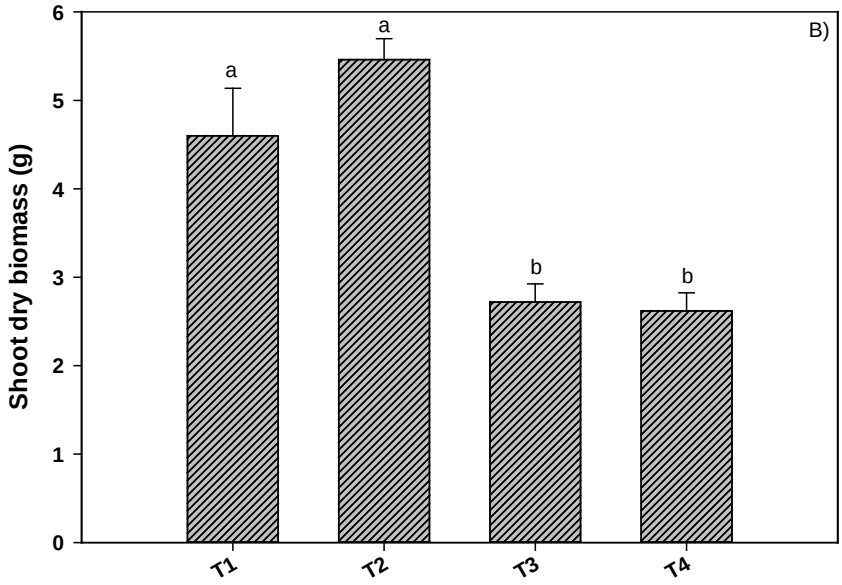


Figure 3. Shoot fresh (A) and dry weight (B) of *S. soda* harvested after 30 days from transplanting. Values represent average of 5 replicates and error bars represent standard error (SE). Similar letters indicate no statistical ($P \leq 0.05$) difference between treatments. (T1soil with EC of 10 dS m^{-1}, T2: soil with EC 10 dS m^{-1} + saline solution, T3: control soil, and T4: control soil + saline solution; see Table 1).

The shoot height was similar amongst all treatments each week but significantly increased with time for each treatment (Fig. 4). The percent increases were 54, 49, 42, and 47% after four weeks for saline soil (T1 and T2) and control soil (T3 and T4), respectively. As the level of soil salinity increases, a salt-induced water stress may occur in plants due to competition for water that is more tightly held by a saline soil.

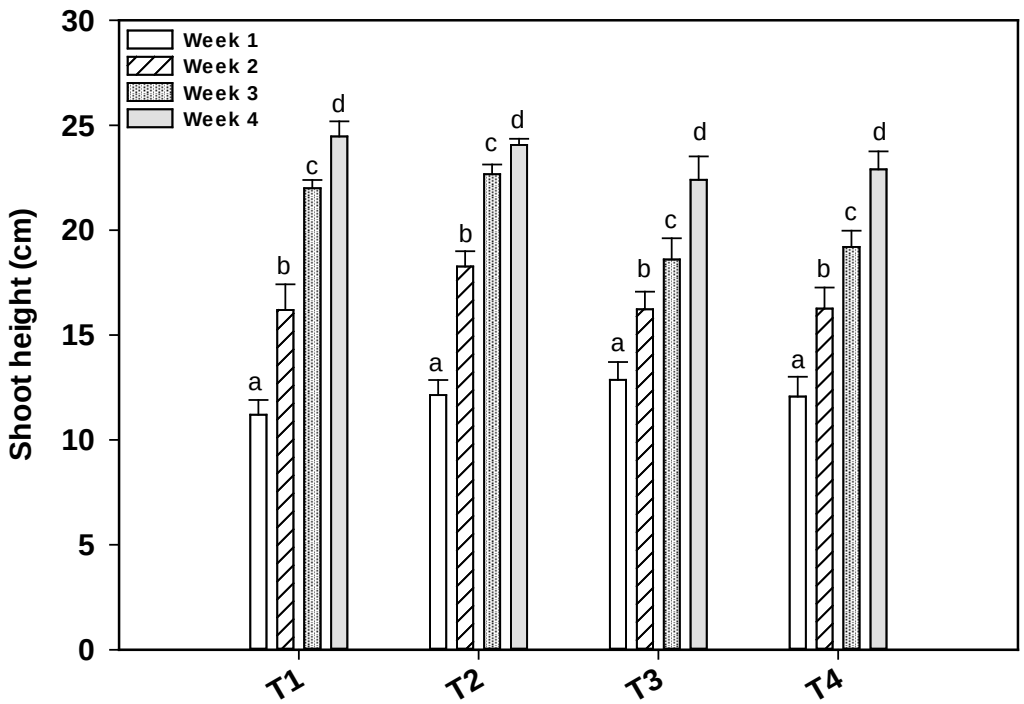


Figure 4. Shoot height measured once a week for four weeks; measurements of height were started when the plants were 20 days old. Values represent average of 5 replicates and error bars represent SE. Similar letters indicate no statistical ($P \leq 0.05$) difference between treatments. (T1soil with EC of 10 dS m^{-1}, T2: soil with EC 10 dS m^{-1} + saline solution, T3: control soil, and T4: control soil + saline solution; see Table 1).

Concentrations of Ca, K, Mg, and P were significantly higher in plant shoots grown on the control soil (T3 and T4) than in the saline soil (T1 and T2) (Fig. 5). At harvest,

concentrations of total and water soluble P were significantly higher in control soil compared to saline soil (Table 2).

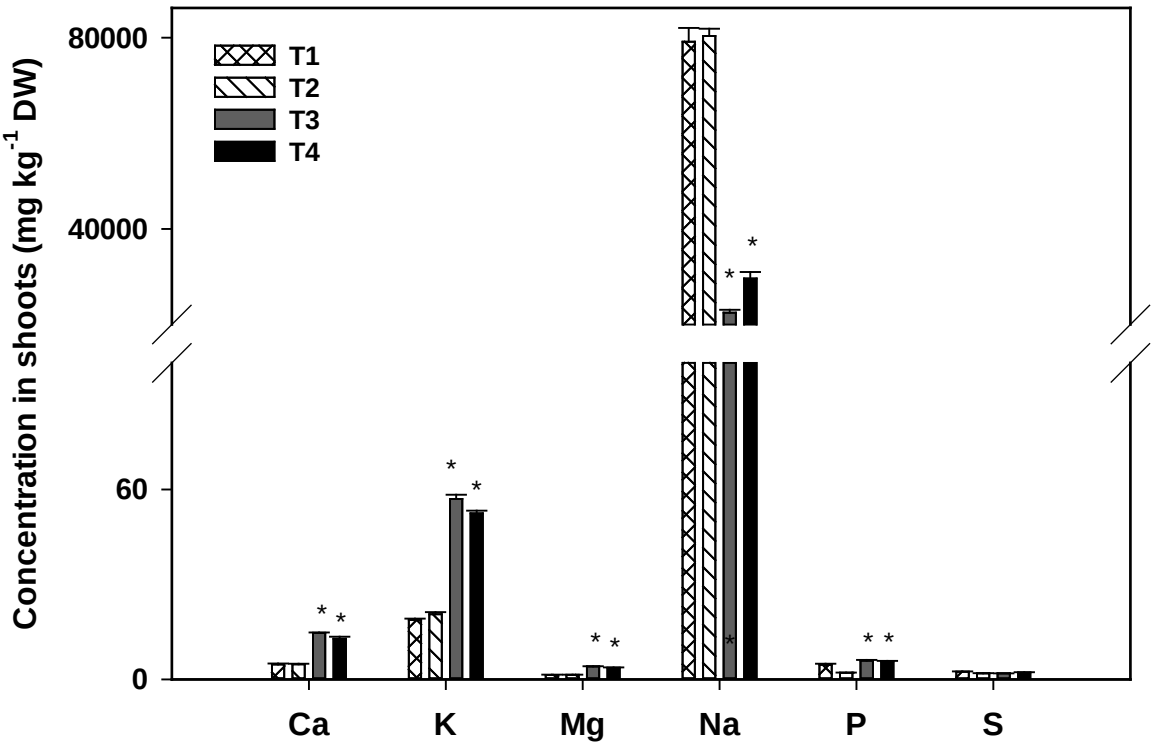


Figure 5. Concentration of Ca, K, Mg, Na, P, and S in *S. soda* shoot at harvest after 30 days from transplanting. Values represent average of 5 replicates and error bars represent SE. Stars (*) indicate statistical ($P \leq 0.05$) difference between treatments for each element listed. (T1soil with EC of 10 dS m^{-1}, T2: soil with EC 10 dS m^{-1} + saline solution, T3: control soil, and T4: control soil + saline solution; see Table 1).

Concentrations of total and water soluble Ca and Mg were higher in saline soil at harvest, whereas total and water extractable concentrations of K in soil were higher in control soil at harvest (Table 2). The lower uptake of K, Ca and Mg in plants grown on saline soil relative to plants grown on control soil can be due to the selective preference for uptake of Na and Cl by *S. soda* from the saline soil, which contains higher concentrations of Na and Cl than control soil.

Concentrations of Ca and Mg in the plants grown on saline soils are comparable to those reported by Watson and O'Leary (1993) for the various halophyte species grown on saline-alkaline field soils in the west side of the SJV. Similar results were also obtained by Díaz et al. (2013) who evaluated the performance of six different halophytes irrigated with saline drainage water in the west side of the SJV. They found that two plant species, *Distichilis spicata* L. and *Allenrolfea occidentalis* S. Wats., had similar Ca and Mg concentrations in shoots compared to those concentrations obtained in *S. soda* grown on saline soil in our study. Milić et al. (2013) reported comparable concentrations of Na, Ca, K, and Mg in shoots of *S. soda* grown in saline areas in the Republic of Serbia, indicating that the plant accumulated more Na than K, Mg, and Ca with a decreasing uptake of the ions in the order of Na>>K>Ca>Mg.

S. soda grown on saline soil (T1and T2) accumulated 8% Na (Fig. 5) in dry matter, which is comparable to values obtained in *Atriplex* species (Watson and O'Leary, 1993) but lower than those obtained in dwarf saltwort (*Salicornia bigelovii*) grown on saline soil in the SJV (Díaz et al., 2013). In our study, an almost linear relationship was observed between water extractable soil Na and the Na concentration in shoots at harvest (Fig. 6) for all treatments with a Pearson correlation coefficient of $r=0.96$ ($P \leq 0.05$).

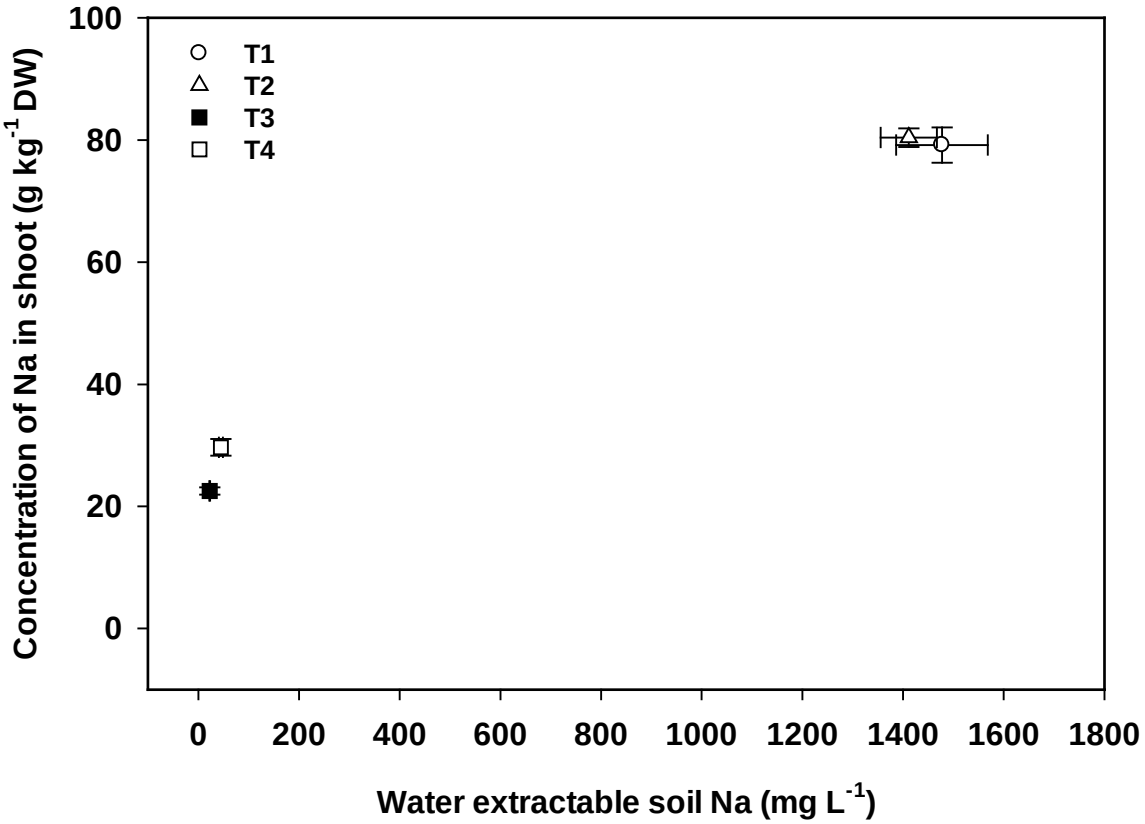


Figure 6. Relation between water extractable Na in soil and concentration of Na in shoots. Values represent average of five replicates and error bars represent SE. (T1soil with EC of 10 dS m^{-1}, T2: soil with EC 10 dS m^{-1} + saline solution, T3: control soil, and T4: control soil + saline solution; see Table 1).

Our results demonstrate that *S. soda* accumulates and tolerates very high levels of Na in the shoots, a characteristic needed for a plant to be considered as a viable alternative crop for the arid saline soils as those of the central west SJV. Similarly, the uptake of Cl in plants grown on saline soil (T1 and T2) was significantly higher than in control soils (T3 and T4) (Fig. 7), due to the significantly higher concentrations of Cl in saline soil (T1 and T2) (Table 3). Chloride concentrations in shoot are comparable to those reported by Díaz et al. (2013) for *Atriplex* grown in saline soils of the SJV. In addition, *S. soda* was able to tolerate high levels of salinity (EC≥10

dS m^{-1}) and it showed increases in fresh and dry weight with increased soil EC (Fig. 8), indicating that salinity improved plant growth.

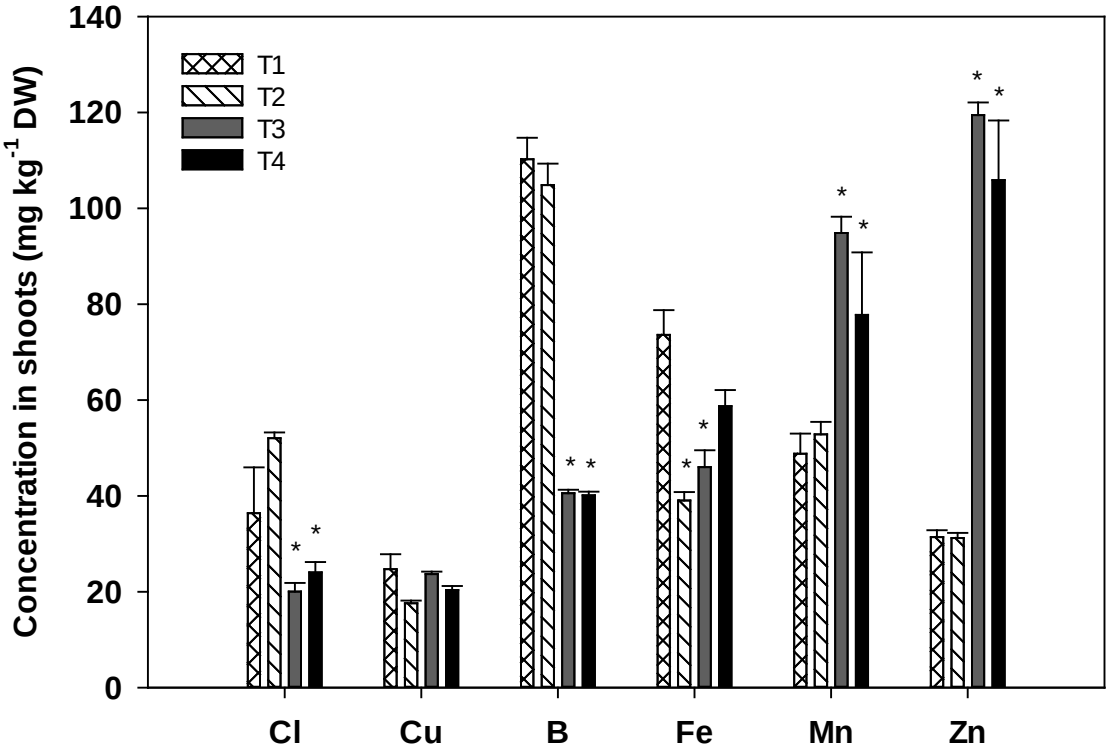


Figure 7. Concentration of Cl, Cu, B, Fe, Mn, and Zn in *S. soda* shoot at harvest 30 days after transplanting. Values represent average of 5 replicates and error bars represent SE. Stars (*) indicate statistical ($P \leq 0.05$) difference between treatments for each element listed. (T1soil with EC of 10 dS m^{-1}, T2: soil with EC 10 dS m^{-1} + saline solution, T3: control soil, and T4: control soil + saline solution; see Table 1).

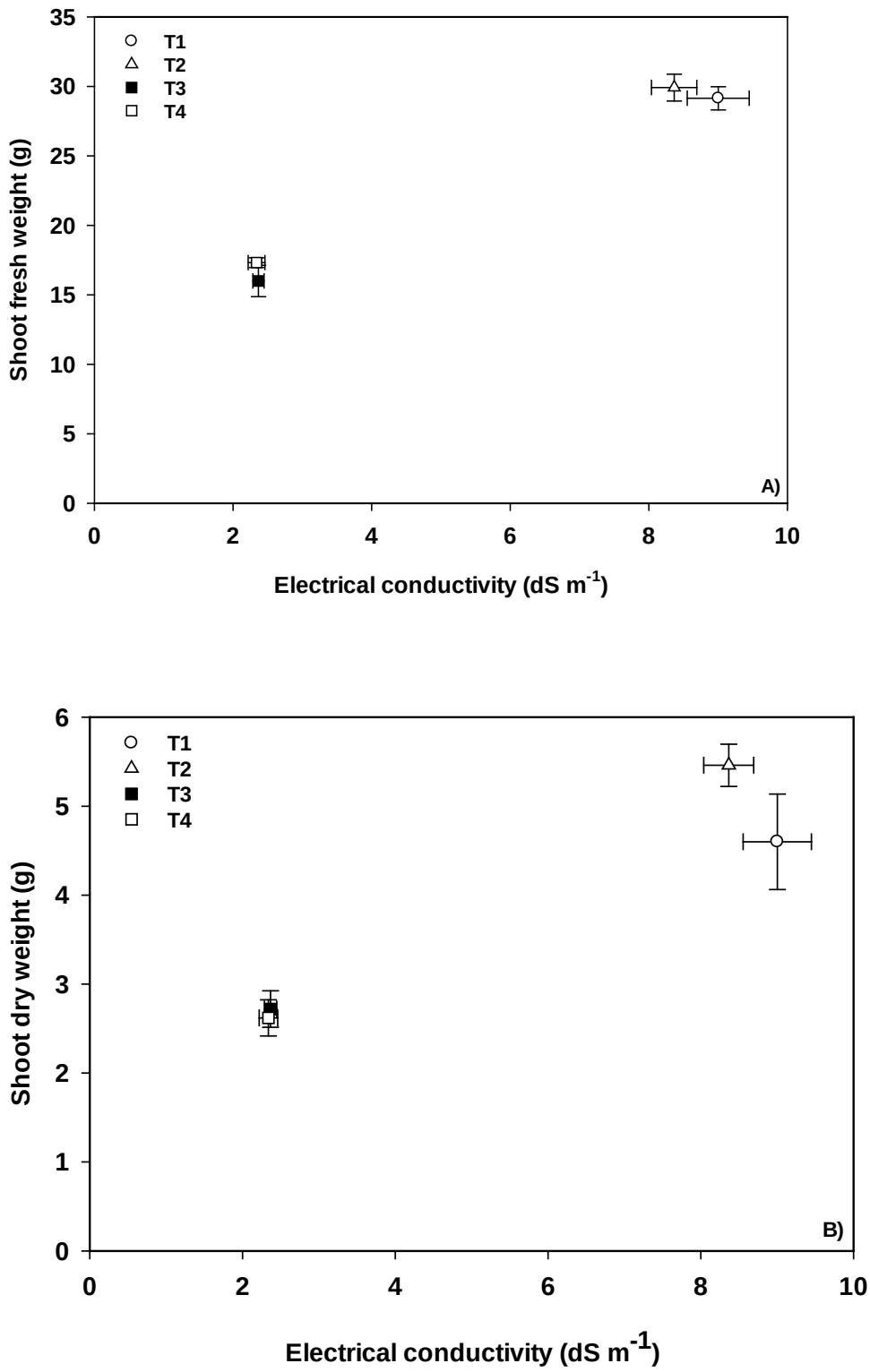


Figure 8. Relationship between electrical conductivity and shoot fresh weight A) and dry weight B). Values represent average of five replicates and error bars represent SE. (T1soil with EC of 10

dS m^{-1}, T2: soil with EC 10 dS m^{-1} + saline solution, T3: control soil, and T4: control soil + saline solution; see Table 1).

In *Atriplex* and *Halimione* species, salinity tolerance is ascribed to specific mechanisms by which the plant can localize salts in specialized compartments (i.e. trichomes on the leaves) or excrete salts outside the plant tissues (i.e. onto the leaf surface). In general, in succulent-like halophytes species such as *Salicornia*, *Salsola*, and *Suaeda*, salts are accumulated in the vacuoles. For example, vacuoles occupy more than 70% of the leaves mesophyll cells in *Suaeda maritima*, which has the ability to store salts at concentrations higher than 500 mM (Hajibagheri et al., 1984).

S. soda did not show any symptoms of B toxicity when grown on saline soil (T1 and T2) containing >10 mg L^{-1} water extractable B. The concentration of B in the shoots showed an almost linear relationship with the water extractable B in soil at harvest (Fig. 9) with a Pearson correlation coefficient of $r=0.91$ ($P\leq0.05$). The plant B levels reported here are comparable to those reported by Díaz et al. (2013) and Watson et al. (1994) for *Distichils spicata* and *Atriplex* species grown under field conditions in the SJV and irrigated with saline drainage water for 4-6 years. In this study, the plants grown on saline soil (T1 and T2) accumulated 100 mg B kg^{-1} DW in only 4 weeks (Fig. 7), indicating that *S. soda* could be useful for phyto-management of B in soil and water, as described in Tassi et al. (2011).

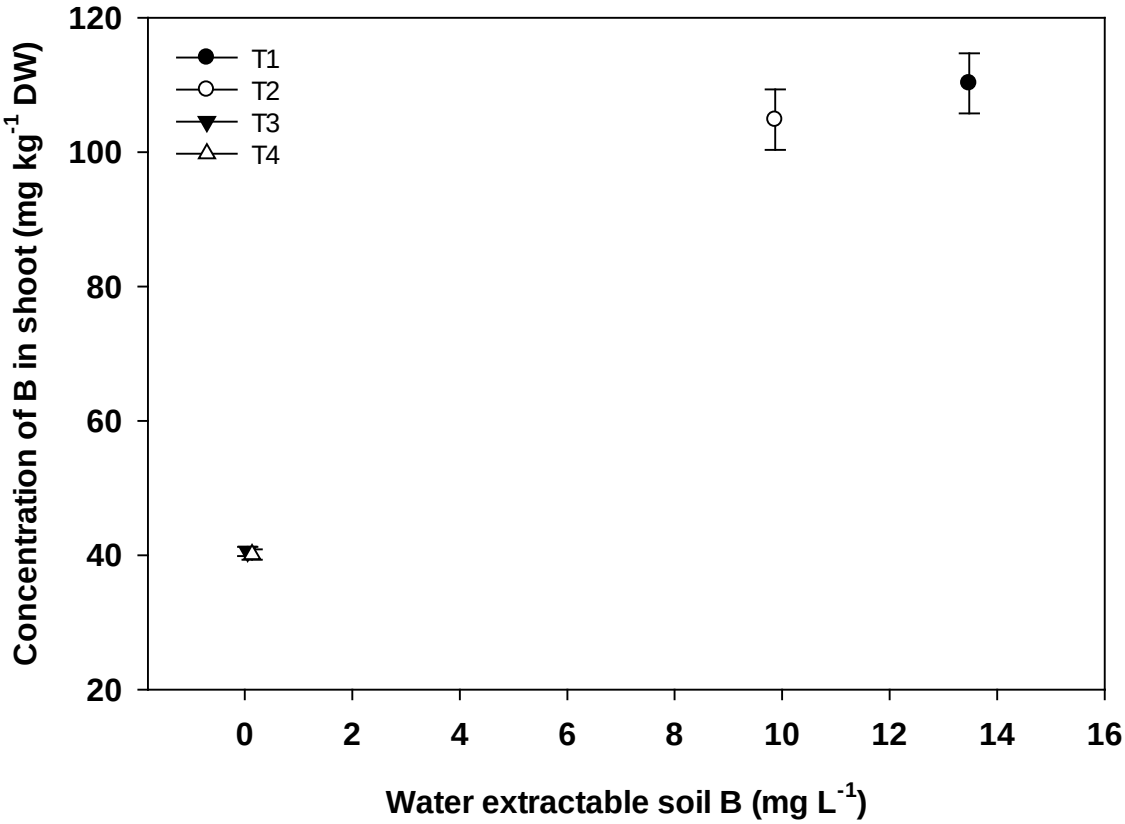


Figure 9. Relation between water extractable B in soil and concentration of B in shoots. Values represent average of five replicates and error bars represent SE. (T1soil with EC of 10 dS m^{-1}, T2: soil with EC 10 dS m^{-1} + saline solution, T3: control soil, and T4: control soil + saline solution, see Table 1).

Excessive levels of B (i.e. >4 mg L^{-1}) in soils can cause substantial losses in normal crop productivity (Maas, 1990). Leaching B out of the soil profile is sometimes used as a strategy to remediate excessive soluble B in soils but this method is unpractical in arid and semi-arid regions, especially because there is no water available. Importantly, leaching B from soils requires almost 3 times more water than that needed to leach salinity (Oster and Rhoades, 1975). Using salt and B tolerant plants to help manage high soluble B levels in soil and water should at least be considered as a management tool for high saline and B soils. Uptake of B by *S. soda* in

our study was about 2 times less that by the B tolerant species *Puccinellia distans* that accumulated about ~1 mg B in plant shoot when exposed to 10 mg B L^{-1} in solution (Stiles et al., 2010). However, in the latter study *P. distans* was grown hydroponically and B was supplied for 6 weeks as part of saline solution, thus eliminating the chemical and biological complexity of B interactions with the soil. In our experiment, *S. soda* was able to take up significant amounts of B in 30 days.

S. soda accumulated about 3-4 mg kg^{-1} of Se when grown on saline soil (T1 and T2) (Fig. 10) and 0.5 mg kg^{-1} when grown on control soil irrigated with 0.25 mg kg^{-1} Se in the saline solution (Fig. 10). There was a linear relationship between concentration of Se in shoot and water extractable Se in soil (Fig. 11) with a Pearson correlation coefficient of $r=0.91$ ($P \leq 0.05$). Hence, it appears that *S. soda* is a moderate Se accumulator species and its harvested plant parts could be considered as a Se-enriched vegetable. In this regard, selenium is an essential micronutrient for humans and the consumption of Se-enriched 'agretti' could be integrated for use of an additional source of Se in Se deficient regions around the world (White and Broadley, 2009).

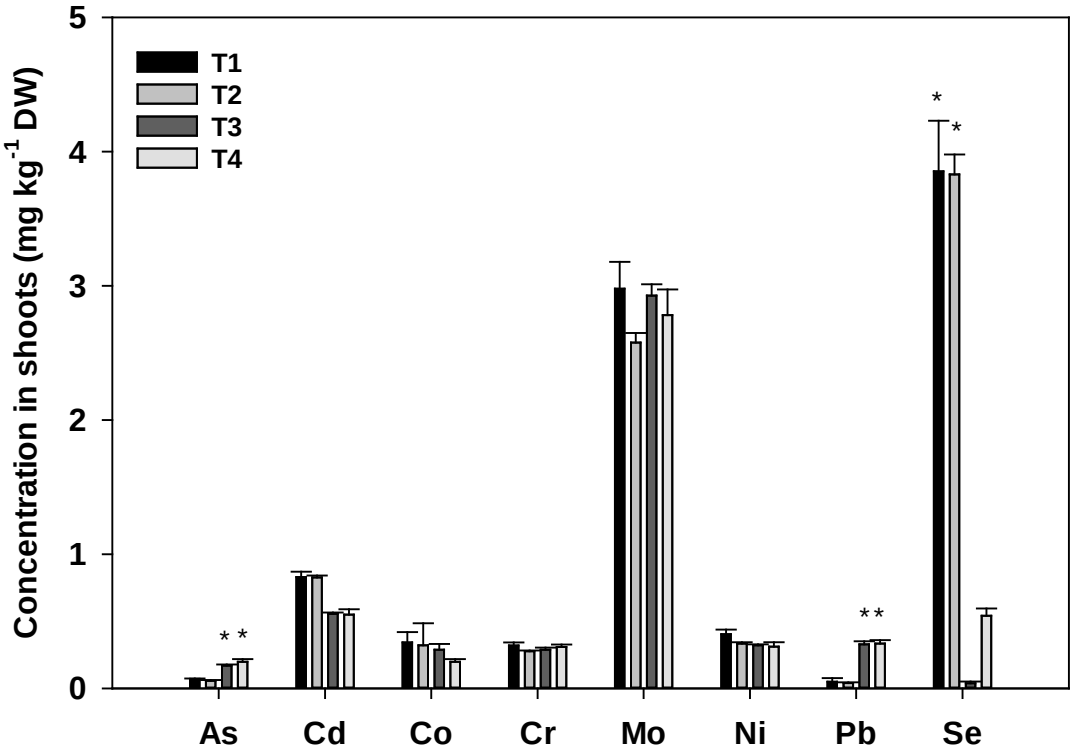


Figure 10. Concentration of As, Cd, Co, Cr, Mo, Ni, Pb, and Se in *S. soda* shoot at harvest after 30 days from transplanting. Values represent average of 5 replicates and error bars represent SE. Stars (*) indicate statistical ($P \leq 0.05$) difference between treatments for each element listed. (T1soil with EC of 10 dS m^{-1}, T2: soil with EC 10 dS m^{-1} + saline solution, T3: control soil, and T4: control soil + saline solution, see Table 1).

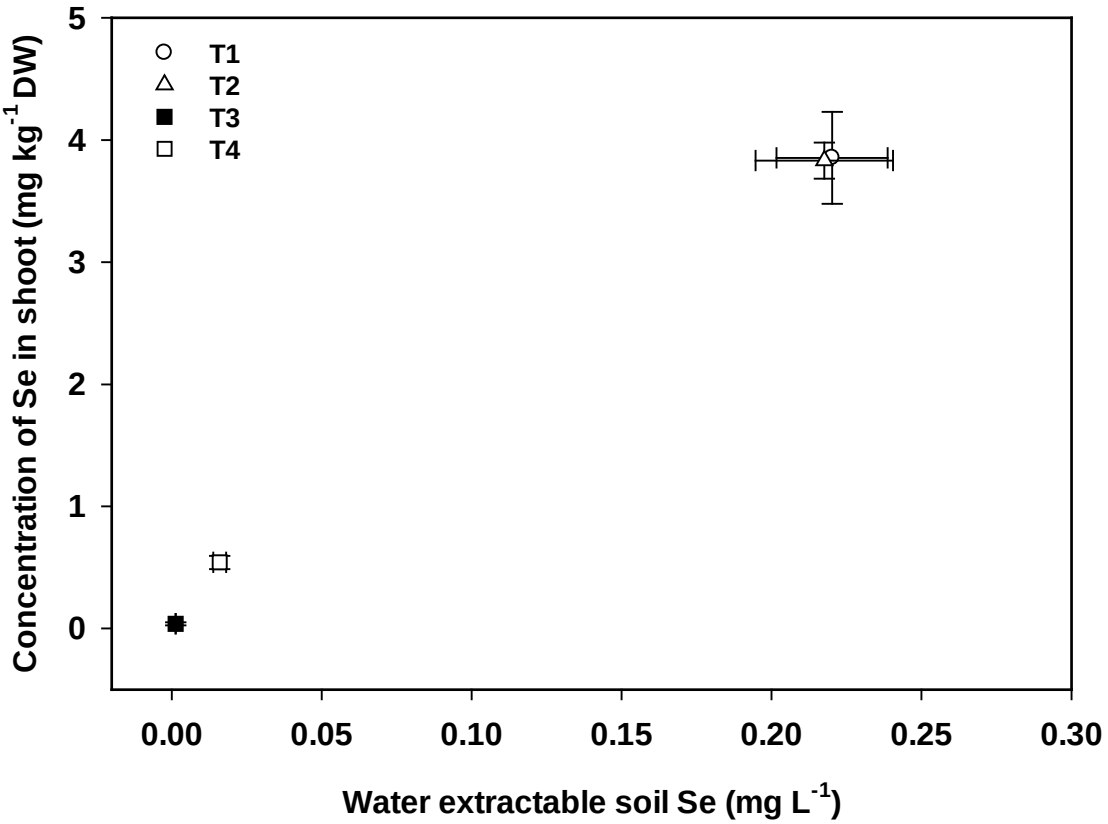


Figure 11. Relation between water extractable Se in soil and concentration of Se in shoots. Values represent average of five replicates and error bars represent SE(T1soil with EC of 10 dS m^{-1}, T2: soil with EC 10 dS m^{-1} + saline solution, T3: control soil, and T4: control soil + saline solution, see Table 1).

Currently, phyto-management strategies for soluble Se and B in the west side of central California rely on the use of moderately tolerant plant species such as Indian mustard (*Brassica juncea* L.) and canola (*Brassica napus* L.). However, the concentration of Se found in *S. soda* after exposure to Se-laden soil for only 30 days under greenhouse conditions is similar and even higher than other species, as reported by Bañuelos (1996). Therefore, *S. soda* should be further evaluated for its ability to accumulate Se in field soils under various environmental conditions.

Some authors have proposed the use of halophytes as optimal candidates for phytostabilization and phytoextraction of heavy metal contaminated saline soils (Wang et al., 2014, Manousaki and Kalogerakis, 2011). Although the evaluation of *S. soda* as a potential halophyte for phytostabilization of metal contaminated saline soil was not the goal of this study, we analyzed its potential impact on the uptake of micro-nutrients, and trace elements and we discuss the results in the following section.

In *S. soda*, iron concentrations remained in the range of adequate for normal metabolic activities for halophytes such as *Atriplex* species (Lefèvre et al., 2009) and the uptake of Fe was significantly higher in the saline soil irrigated with good quality water (T1) compared to the same saline soil irrigated with the saline solution (T2) (Fig. 7). Uptake of S (Fig. 5), Cu (Fig. 7), Cd, Co, Cr, Mo, and Ni (Fig. 10) were similar among all treatments, while the uptake of Mn and Zn (Fig. 7) and As and Pb (Fig. 10) were significantly higher in plants grown on control soil (T3 and T4) relative to saline soil (T1 and T2). *S. soda* was able to take up trace elements at higher concentrations when their availability was higher in the soil solution (Table 3). However, there was no linear relationship between plant uptake (mg kg^{-1}) and water extractable metals in soil (mg L^{-1}) in contrast to the linear relationships observed for Na (Fig.6), B (Fig. 9), and Se (Fig. 10) in shoot and soil. These observations indicate that *S. soda* can absorb soluble metals but the plant might limit the shoot-to-root translocation, thus behaving more like a an excluder rather than an accumulator (Baker, 1981). Milić et al. (2012) evaluated the ability of various halophyte species to absorb different heavy metals from inland and maritime saline areas and amongst the various halophyte studied, *S. soda* showed the lowest transfer factor ($[metal]_{shoot}/[metal]_{soil}$) for all investigated metals (Co, Cr, Cu, Fe, Mn, Ni, and Zn). Mendez and Maier (2008) describe in their review on the phytostabilization of metal in arid and semi-arid environments that it is

important to use drought- and salt-tolerant plant species that are metal tolerant and do not accumulate (>1% dry biomass) metals in the above-ground biomass. Otherwise, the plants might be a source of metal exposure to foraging animals and to wildlife. According to our results, *S. soda* could be a potential plant species to be used in phytostabilization projects and further studies are needed to elucidate its potential in soils with high concentration of trace metals under saline conditions.

4. Conclusion

With the rapid spread of salinity and water shortage exacerbated by climate changes, cultivation of drought-tolerant and salt accumulator plants can help address food security challenges and the increasing demand for resource efficient agricultural products. In our study we showed that *S. soda* safely tolerates the saline (soil EC >10 dS m^{-1}) and B-laden (10 mg L^{-1}) soils of the west side of central California and it can accumulate high concentrations of Na, B, and Se without showing any toxicity symptoms. Therefore, *S. soda* showed promising potential as an alternative crop or vegetable, and as management plant for excessive soluble Na, B, and Se in soil. The plant species should be further evaluated for its ability to accumulate soluble B and Se in other regions of the western United States.

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References

Baker AJM. 1981. Accumulators and excluders -strategies in the response of plants to heavy metals. *Journal of Plant Nutrition,* **3**: 643-654.

Bañuelos GS. 1996. Managing high levels of boron and selenium with trace element accumulator crops. *Journal of Environmental Science and Health - Part A Toxic/Hazardous Substances and Environmental Engineering,* **31**: 1179-1196.

Bañuelos GS. 2001. The green technology of selenium phytoremediation. *BioFactors,* **14**: 255-260.

Bañuelos GS. 2002. Bioremediation and biodegradation: Irrigation of broccoli and canola with boron- and selenium-laden effluent. *Journal of Environmental Quality,* **31**: 1802-1808.

Bañuelos GS, Akohoue S. 1994. Comparison of microwave digestion with block digestion for selenium and boron analysis in plant tissues. *Communications in Soil Science and Plant Analysis,* **25**: 1655-1670.

Bañuelos GS, Lin ZQ. 2010. Cultivation of the Indian fig Opuntia in selenium-rich drainage sediments under field conditions. *Soil Use and Management,* **26**: 167-175.

Bañuelos GS, Meek DW. 1990. Accumulation of selenium in plants grown on selenium-treated soil. *Journal of Environmental Quality,* **19**: 772-777.

Colla G, Rouphael Y, Fallovo C, Cardarelli M, Graifenberg A. 2006. Use of *Salsola soda* as a companion plant to improve greenhouse pepper (*Capsicum annuum*) performance under saline conditions. *New Zealand Journal of Crop and Horticultural Science,* **34**: 283-290.

Díaz FJ, Benes SE, Grattan SR. 2013. Field performance of halophytic species under irrigation with saline drainage water in the San Joaquin Valley of California. *Agricultural Water Management,* **118**: 59-69.

Graifenberg A, Botrini L, Giustiniani L, Filippi F, Curadi M. 2003. Tomato growing in saline conditions with biodesalinating plants: *Salsola soda* L., and *Portulaca oleracea* L. *Acta Horticulturae,* **609**: 301-305.

Hajibagheri MA, Hall JL, Flowers TJ. 1984. Stereological analysis of leaf cells of the halophyte *Suaeda maritima* (L.) dum. *Journal of Experimental Botany,* **35**: 1547-1557.

Institute S. 1989. *SAS procedures guide.* N.C.

Lefèvre I, Marchal G, Meerts P, Corréal E, Lutts S. 2009. Chloride salinity reduces cadmium accumulation by the Mediterranean halophyte species *Atriplex halimus* L. *Environmental and Experimental Botany,* **65**: 142i-152.

Lorestani B, Cheraghi M, Yousefi N. 2011. Accumulation of Pb, Fe, Mn, Cu and Zn in plants and choice of hyperaccumulator plant in the industrial town of Vian, Iran. *Archives of Biological Sciences,* **63**: 739-745.

Maas EV. 1990. Crop salt tolerance. *American Society of Civil Engineers, Manuals and Reports on Engineering Practice.* ASCE. New York, NY, United States.

Manousaki E, Kadukova J, Papadantonakis N, Kalogerakis N. 2008. Phytoextraction and phytoexcretion of Cd by the leaves of *Tamarix smyrnensis* growing on contaminated non-saline and saline soils. *Environmental Research,* **106**: 326-332.

Manousaki E, Kalogerakis N. 2009. Phytoextraction of Pb and Cd by the Mediterranean saltbush (*Atriplex halimus* L.): Metal uptake in relation to salinity. *Environmental Science and Pollution Research,* **16**: 844-854.

Manousaki E, Kalogerakis N. 2011. Halophytes-an emerging trend in phytoremediation. *International Journal of Phytoremediation,* **13**: 959-969.

Mendez MO, Maier RM. 2008. Phytostabilization of mine tailings in arid and semiarid environments - An emerging remediation technology. *Environmental Health Perspectives,* **116**: 278-283.

Milić D, Luković J, Ninkov J, Zeremski-Škorić T, Zorić L, Vasin J, Milić S. 2012. Heavy metal content in halophytic plants from inland and maritime saline areas. *Central European Journal of Biology,* **7**: 307-317.

Milić D, Luković J, Zorić L, Vasin J, Ninkov J, Zeremski T, Milić S. 2013. Halophytes relations to soil ionic composition. *Journal of the Serbian Chemical Society,* **78**: 1259-1268.

Ohlendorf HM, Hoffman DJ, Saiki MK, Aldrich TW. 1986. Embryonic mortality and abnormalities of aquatic birds: Apparent impacts of selenium from irrigation drainwater. *Science of the Total Environment,* **52**: 49-63.

Oster JD, Rhoades JD. 1975. Calculated drainage water compositions and salt burdens resulting from irrigation with river waters in the Western United States. *Journal of Environmental Quality,* **4**: 73-79.

Presser T, Schwarzbach S. 2008. *Technical analysis of in-valley drainage management strategies for the western San Joaquin Valley, California*: US Geological Survey.

Schoups G, Hopmans JW, Young CA, Vrugt JA, Wallender WW, Tanji KK, Panday S. 2005. Sustainability of irrigated agriculture in the San Joaquin Valley, California. *Proceedings of the National Academy of Sciences of the United States of America,* **102**: 15352-15356.

Stiles AR, Bautista D, Atalay E, Babaoğlu M, Terry N. 2010. Mechanisms of boron tolerance and accumulation in plants: A physiological comparison of the extremely boron-tolerant plant species, *Puccinellia distans,* with the moderately boron-tolerant *Gypsophila arrostil*. *Environmental Science and Technology,* **44**: 7089-7095.

Tassi EL, Pedron F, Barbafieri M. 2011. Evaluating the absorption of boron by plants - A potential tool to remediate contaminated sediments from Cecina River basin in Italy. *Water, Air, and Soil Pollution,* **216**: 275-287.

Török P, Kapocsi I, Deák B. 2012. Conservation and management of alkali grassland biodiversity in Central Europe. In: Zhang W-J, ed. *Grasslands: Types, Biodiversity and Impacts*. Haupppage, New York: Nova Science Publishers.

Tundis R, Menichini F, Conforti F, Loizzo MR, Bonesi M, Statti G, Menichini F. 2009. A potential role of alkaloid extracts from Salsola species (Chenopodiaceae) in the treatment of Alzheimer's disease. *Journal of Enzyme Inhibition and Medicinal Chemistry,* **24**: 818-824.

Wang HL, Tian CY, Jiang L, Wang L. 2014. Remediation of heavy metals contaminated saline soils: A halophyte choice? *Environmental Science and Technology,* **48**: 21-22.

Watson MC, Banuelos GS, O'Leary JW, Riley JJ. 1994. Trace element composition of Atriplex grown with saline drainage water. *Agriculture, Ecosystems and Environment,* **48**: 157-162.

Watson MC, O'Leary JW. 1993. Performance of Atriplex species in the San Joaquin Valley, California, under irrigation and with mechanical harvests. *Agriculture, Ecosystems and Environment,* **43**: 255-266.

White PJ, Broadley MR. 2009. Biofortification of crops with seven mineral elements often lacking in human diets - Iron, zinc, copper, calcium, magnesium, selenium and iodine. *New Phytologist,* **182**: 49-84.