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Presidential Address

Donald L. Sparks, Past President, SSSA

I deeply appreciate the honor and opportunity of serving as President of SSSA this past year. It has been an experience that I will always fondly remember and cherish. In this editorial, I want to provide you with a brief summary of some of the activities and accomplishments that have occurred during the past year, and some plans and thoughts for the future.

During the past few years, your officers and many members have worked diligently to enhance the visibility and identity of soil science and SSSA. The SSSA Identity and Visibility Committee, chaired by Randy Brown, has developed an excellent new Careers in Soil Science brochure that will be distributed widely to students, teachers, and counselors. This brochure should be extremely helpful in recruiting future soil scientists and SSSA members. Soil Science curricula are also being developed for young persons in 4-H clubs. These curricula could reach potentially 6 million 4-H members in the USA and many more abroad. As all of you know, enrollments of both undergraduate and graduate students in soil science are decreasing in most places, and we must do everything we can to excite young persons about our discipline and career opportunities.

We will also soon shoot a segment dealing with our new slogan "Soils Sustain Life" that will show, from multiple scales, ranging from the global to the nanoscale, the importance of soils in sustaining agriculture, the environment, and humankind. This segment will be part of the critically acclaimed "American Environmental Review" Series hosted by Morley Safer and will be aired on Public Television in the USA and internationally on World Net. We could potentially reach 50 million households.

During the past year, SSSA has disseminated a position statement on nutrient management, and a new position statement on carbon sequestration will be completed. These will be extremely useful to our Director of Science Policy, our Congressional Fellows, and all of us as we interact with Congressional staff, policymakers, stakeholders, laypersons, and federal agencies on important issues in this country and abroad and press for increased funding.

We must stay ahead of the curve on developing issues in which we need to be a major player. To help in this regard, we have recently appointed two new committees, Emerging Issues in Soil Science and Urban Soils. The Emerging Issues in Soil Science Committee is chaired by Carolyn Olson. The charge to this committee is: to review the need for and scope of possible SSSA position papers, to identify emerging issues in soil science, to determine funding opportunities for soil science research and programs, to assist in development of liaisons with federal agencies and national laboratories, to provide information to the Director of Science Policy on emerging issues in soil science, and to develop documents for federal agencies relative to research needs in soil science.

With regard to the latter three items, we are making good progress in enhancing our visibility and identity in federal funding agencies. We have visited with program officers in USDA, NSF, DOE, EPA, and NASA about greater funding opportunities in soil science and have suggested names of soil scientists who could serve on advisory committees and review panels. We must all let our state and federal legislators know that funding for soil science, and indeed for all of science, is absolutely essential if we are to continue to have a strong economy and a superb quality of life.

I would strongly suggest that you do what you can to see that funding is significantly increased for the USDA's National Research Initiative Competitive Grants Program, that funding continues for the IFAS program, and that there is more USDA funding across the board. USDA's funding pales besides that for NIH, NSF, DOE, and other agencies. This is indeed shameful in view of the contributions that agriculture has made and continues to make to our economy and lifestyle.

I have been greatly encouraged over the past year by enhanced visibility of soil science in NSF and the splendid funding opportunities for soil scientists. Major initiatives in molecular environmental science and biocomplexity, and nanophases, have been mounted, and a number of our members have received funding from these programs. One of the exciting aspects of these programs is the opportunity for soil scientists to work closely with chemists, physicists, biologists, economists, and engineers to train students in interdisciplinary programs and to tackle complex issues and problems facing society. I have been impressed with several such programs around the USA that involve soil scientists.

The Committee on Basic Opportunities in Earth Science of the National Research Council has recently issued its report. They have identified six specific priority areas for enhanced basic research, including: "integrative studies of the critical zone (the near surface environment in which complex interactions involving rock, soil, water, air, and living organisms regulate the natural habitat and determine the availability of life-sustaining resources), geobiology, and research on earth materials that employs advanced technology to determine properties at the molecular level for understanding materials and processes at all scales relevant to planets". Additionally, the report recommends that the Earth Sciences Division of NSF enhance multidisciplinary studies of the critical zone, with special emphasis on strengthening soil science and investigations on coastal zone processes, and that it increase long-term support for individual investigator–driven science. We all owe Larry Wilding a great deal of gratitude for his fine efforts in serving on this very important committee.

The U.S. National Committee on Soil Science (USNC/SS), ably chaired by Wilford Gardner, provides a valuable link to the National Academy of Sciences. In my view, this committee will have a major impact on the future of soil science in the USA and abroad. This past year the Committee, in partnership with SSSA, the NAS, and the Ecological Society of America, sponsored a national forum in Washington, DC on carbon sequestration, and possible NRC studies are being discussed on the latter topic and on soil degradation and soils and human health.

This past September, SSSA and the German Society of Soil Science held their first joint congress in Osnabrueck, Germany on the role of soils in agro-ecosystems. The congress was extremely successful. I am pleased to announce that we will jointly hold a meeting with the Czech Society of Soil Science next September in Prague.

All of us are excited about SSSA, in conjunction with the USNC/SS and the NAS, hosting the 18th World Congress of Soil Science (WCSS), July 10–15, 2006 in Philadelphia. The theme of the Congress is "Frontiers of Soil Science: Technology and the Information Age". This is the first WCSS in the USA since 1960, when we hosted the Congress in Madison, WI. We have a tremendous opportunity to showcase the importance of soil science to our country and the world.

Our future as a discipline and Society is indeed bright, but we face challenges. We must increase the diversity of SSSA in terms of ethnicity, gender, and type of member. We need to reach out more to practicing professionals and ensure that we provide them with membership services that meet their needs. We must preserve the identity of our discipline, but increasingly interact with colleagues in other fields. Additionally, we must become more proactive in communicating to policymakers and the public about issues that we are experts in, increase overall membership in SSSA, particularly nontraditional members and graduate students, and excite young persons about soil science.

I am confident that we can meet these and other challenges and build on the remarkable successes we have had as a discipline and a Society. Again, many thanks for your support and encouragement.

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SSSA PUBLICATION POLICY

Soil Science Society of America (revised 5 February 2000)

Publication Policy

The initial policy statement was prepared by the 1963 Organization and Policy Committee of SSSA to provide details not covered in the Bylaws of SSSA. The publication policy is intended to provide members of the Society a more complete statement of policy than has been available heretofore and to answer most questions about policy and procedures for different kinds of subject matter and publications. The policy is subject to change at will by the Board of Directors within the broad limits set by the Bylaws.

I. General Policy

1. Publications of the Soil Science Society of America are under the supervision of the editorial board, which consists of *(a)* the editor-in-chief, *(b)* the managing editor, *(c)* technical editors, *(d)* enough associate editors to carry out editorial duties promptly and to provide each division with at least one associate editor, *(e)* editors appointed for temporary service on particular publications, and *(f)* the executive vice president and the associate executive vice president as ex officio members.

2. Membership in the Society is not a requirement for publication in *SSSA Journal.* However, nonmembers will be charged an additional amount, to be determined by the Board of Directors, in page charges for the first six published pages of a manuscript; nonmember authors will pay the same production charges as members for pages after six. The basis for making a decision on charging nonmember page charges will be the author's membership status on the date the manuscript is accepted for publication. Membership as used in this context includes active, emeritus, graduate student, and undergraduate student membership in the Soil Science Society of America, the Crop Science Society of America, or the American Society of Agronomy.

3. Costs of publication are met by dues and other Society income and by page and production charges to authors or their sponsoring organizations as determined from time to time by the Board of Directors. Publication charges to authors may be waived upon application to the President when scientific merit and financial hardship can be demonstrated. Society members must be given a one-year notice before a change in operating procedure for page and production charges can be put into effect.

4. All material intended for publication by the Society should be written in English and should be sent to the editor or, for publications other than the *SSSA Journal*, to a special editor appointed by the SSSA President.

5a. In matters of review, revision, and approval of manuscripts, the editorial board corresponds directly with the authors.

5b. A technical editor committee of the editorial board, consisting of the editor-in-chief, editor, and technical editors, will make decisions concerning requests for rapid publication, publication of symposia, and other related matters. This committee may consult with associate editors for additional opinion as appropriate. This committee will seek and approve invited papers for *SSSA Journal.*

6. Volunteered papers that are not a part of any organized symposium at annual meetings of the Society do not require release by the editor-in-chief. Such papers, however, may not be published elsewhere before the oral or poster presentation. Symposium and invited papers based on oral or poster presentations are released automatically for publication by the American Society of Agronomy or the Crop Science Society of America upon notification of the editor-in-chief. However, SSSA encourages that papers presented at Society meetings be published in Society publications.

II. Procedures and Regulations for Different Types of Contributions

A. Original Research Findings

1. Original research findings are interpreted to mean the outcome of scholarly inquiry, investigation, or experimentation having as an objective the revision of existing concepts, the development of new concepts, or the development of new or improved techniques in some phase of soil science.

2. The *SSSA Journal* is the normal channel for the publication of papers reporting original research findings. A regular article may be published as a rapid communication, without waiting its turn, if justified by the corresponding authors and approved by the technical editor committee. Short papers (normally less than two printed pages) may be submitted as Notes. These may be published as rapid communications, without waiting their turns, if justified by the corresponding authors and approved by the technical editor committee. Papers and Notes may be submitted at any time for publication in the *SSSA Journal*, whether presented at the annual meetings or not.

3. Short papers (normally less than two printed pages in the journal) covering experimental techniques, apparatus, or observations, may be submitted as notes. Notes are not an outlet for papers that are found to be unacceptable as regular articles by the reviewers because of content or state of preparation; however, papers may qualify instead as notes on the basis of the description given above. Review procedures for notes are the same as for regular articles, but obviously, the criteria will differ. A manuscript submitted as a regular article which, in the opinion of the editor, fits instead the criteria of a note, will be reviewed as a note after consultation with the corresponding author. Notes will be published in the most appropriate division of *SSSA Journal* and not in a separate notes section.

4. Papers submitted to the *SSSA Journal* may be transferred to one of the other publications of the Soil Science Society of America, the American Society of Agronomy, or the Crop Science Society of America, provided the author requests the transfer or gives written permission for such transfer, provided the subject matter is appropriate for the publication to which the transfer is proposed, said appropriateness to be determined by the editor of the publication in question, and provided the manuscript meets editorial approval for publication in the outlet to which transfer is proposed. Where a transfer is made, the date of receipt is the date on which the paper was received by the editorial office to which it was submitted originally. Papers submitted originally for publication by one of the associated societies may be accepted for publication by the Soil Science Society of America under the same policy.

5. Manuscripts published in the technical journals of ASA, CSSA, and SSSA must be original reports not previously or

simultaneously published in any other scientific or technical journal. The question of when publication in nontechnical outlets constitutes prior publication must be decided on a case-by-case basis. Recognizing that research scientists often have an obligation to report their findings in nontechnical media prior to publication in technical journals, publication in nontechnical outlets will not be considered prior publication unless essentially all the data and all the conclusions that have been drawn from the data are included in the nontechnical publication.

B. Reviews of Research

1. Short, critical reviews or essays on timely subjects, upon invitation by the technical editor committee, may be published in a special section of the *SSSA Journal.* This section shall not exceed 48 pages per year. Page and production charges for invited review papers are waived.

2. Extensive reviews of research may be published in the *Agronomy* monograph series (by ASA, CSSA, or SSSA), or in the SSSA book series. They may be appropriate for publication in the Soil Science Society of America Special Publication series, depending on the subject, but are not eligible for publication in the *SSSA Journal.* Such reviews usually are prepared only after consultation with the editor of the proposed publication outlet.

C. Monographs and SSSA Book Series

Reviews of research and other manuscripts dealing extensively with a particular subject may be published as an *Agronomy* monograph by ASA, CSSA, or SSSA, or in the SSSA book series. Manuscripts of the nature of monographs on subjects that do not seem appropriate as an *Agronomy* monograph or an SSSA book may be acceptable for publication in the Soil Science Society of America Special Publication series. Preparation of manuscripts for monographs or books is undertaken only after consultation with the chair of the Monographs or Book committee, or with the editor-in-chief.

D. Annual Addresses

Addresses by Society officers and by invited speakers given at the annual general meeting are eligible for publication in the *SSSA Journal.* The manuscripts may be reviewed informally by the technical editor committee but shall require approval only with respect to form and style.

E. Invited Papers

1. The publication policy for invited papers given by Society members at annual meetings is as outlined in *A* and *B*.

2. Invited papers given at annual meetings by nonmembers of the Society who have no members as coauthors are not eligible for publication by the Society unless approval for eligibility is obtained from the president before the invitation is issued. Divisional chairs who wish to issue invitations for papers should obtain this approval through the president-elect, who is the general program chair. The president may seek the advice of the technical editor committee in reaching a decision. Once approval for eligibility has been obtained, the manuscript is handled by the editorial board in accordance with the policy outlined in *A* and *B*. Page charges for such invited papers are waived. Approval for eligibility by the president applies only to publications of the Soil Science Society of America. If the subject matter of the proposed manuscripts appears to fit better in one of the publications of the American Society of Agronomy, prior approval of that Society must be obtained as outlined above or in such other manner as may be specified by that Society. Where eligibility for publication is granted, the divisional chair should make clear to the participants that action by the president does not alter the authority and responsibility of the editorial board to judge the suitability of the manuscript for publication.

F. Symposia Published in *SSSA Journal*

Special publications are the Society's preferred medium for publishing symposia papers; however, it is recognized that under certain circumstances there is benefit to publishing such papers in the *SSSAJ*. Consequently, the following policy statement was developed relative to publication of symposium papers in the journal.

General Policy

The primary reason for publishing symposia in the *SSSAJ* is to report related advances in some aspect of soil science. Published symposia thus provide a coordinated series of mostly original contributions that either advance basic principles or demonstrate important applications of soil science. Except by special approval of the technical editor committee, a single series of symposium papers shall not exceed 60 published pages in a given issue of the journal.

Selection Guidelines

1. Overall originality of research will be the primary criterion governing the selection of symposium papers for publication in the *SSSAJ*. The collective impact of a series of papers as compared to single submissions will also be considered.

2. A symposium series may be introduced by a short, critical review or essay; however, a collection of articles dominated by reviews will not be accepted. In such instances, symposium organizers should consider the possibility of a special publication as a preferred medium for publication.

3. Symposia seeking a synthesis of knowledge through the efforts of two or more divisions of the SSSA or through collaboration with other scientific or professional societies are encouraged. Symposia combining national and international developments in soil science are also encouraged.

Procedure

1. The symposium organizing committee should submit 10 copies of a request for publication to the Editor of the *SSSAJ* at least six months in advance of the actual symposium. The request should include a statement of purpose, a summary of proposed content with the names of authors and approximate titles of papers, an evaluation of the expected impact of the published proceedings, and the names of possible guest editors. If appropriate, the initial request should also indicate any proposed dedication for the symposium.

2. The request will be evaluated in a timely manner by the technical editors committee of the Editorial Board. The committee may seek external advice before reaching a decision. If the request to publish is approved, the committee will also select a guest editor(s) to assist with the review process.

3. Prior to the actual submission of symposium manuscripts to the Editor of the *SSSAJ*, the guest editor(s) must provide a final listing of titles and authors. Corresponding authors should be identified and any waiver of publication costs for non-SSSA members should be verified. Page charges for the publication of papers written by members of the three societies will be the responsibility of member authors. Journal page charges for invited non-members can only be waived by the president, or the president-elect as the president's designee, of the society. It is the responsibility of the guest editor(s) to secure such waivers before an invitation is issued.

4. The guest editor(s) will initially screen all manuscripts from the symposium authors to ensure that manuscripts are in the proper *SSSAJ* format for double blind review [see "Suggestions to Contributors to the *SSSAJ*" Soil Sci. Soc. Am. J. 63(1):vi(1999)]. Additional information is available in the *Publications Handbook and Style Manual* (1998).

5. Manuscripts must be submitted as a group to the *SSSAJ* Editor, normally within 60 days after the symposium is completed. The guest editor(s) shall forward four copies of each properly formatted manuscript to the *SSSAJ* Editor along with the name, address, e-mail address, telephone, and fax numbers of the corresponding author. Recommendations regarding the most appropriate subject matter division for review purposes (S-1 to S-10) and suggestions for suitable reviewers may also be submitted by the guest editor(s).

6. The *SSSAJ* Editor will forward the collection of symposium papers to the proper technical editor. The technical editor will, in turn, distribute the manuscripts to appropriate associate editors who will handle the review process in a manner consistent with that used for non-symposium papers (except as noted in item 7).

7. Anonymous reviews and recommendations will be forwarded directly to the corresponding authors. The guest editor(s) will also receive copies of these comments from the associate editors or the technical editor of the division handling the review. The guest editor(s) is encouraged to work with the authors to properly address all concerns identified in the peer review process and to facilitate timely revision of the manuscripts. Any manuscript not revised within four months of its return for revision is subject to release by the technical editor. Likewise, all decisions regarding final acceptance or release of manuscripts rest with the Editor and technical editor.

8. The guest editor(s) should prepare a preamble of up to one published page for the symposium series. This statement should emphasize the scientific relevance of the subject matter and the implications of reported advances. The statement should *not* be a simple summary of the symposium program. The preamble should be forwarded to the *SSSAJ* Editor with the initial group of manuscripts and may also be subjected to peer review.

9. Dedication of a symposium, up to one published page, may be made for an eminent scientist, group of scientists, or an organization if recommended by the technical editors committee and approved by the Board of Directors. A scientist honored by such a dedication should not be included as an author in the symposium series.

G. Papers in a Joint Program or Symposium with Another Organization

The policy is the same as that outlined in *E* with two exceptions. First, if the individual representing the Soil Science Society of America in arrangements with the other organization is not a divisional chair, this person shall discharge the responsibilities charged to the divisional chair in *E-2*. Second, agreement on publication procedures must be reached between the president of the Soil Science Society of America and the comparable official of the cooperating organization before invitations are issued.

H. Comments and Letters to the Editor

Critical comments on papers published in one of the Society outlets or elsewhere, editorial comment and comments by Society officers, and personal comments on matters having to do with soil science may be published in the *SSSA Journal*. Critical comments by nonmembers on papers published in one of the Society outlets are eligible for publication as are responses by nonmember authors of papers that are criticized in this department, subject to the approval of the manuscript for publication in this form by the technical editor committee. Only where intent of publication is clearly indicated by the author will personal comments be published. Contributions exceeding a length of one printed page in the *SSSA Journal* are generally not eligible for publication as a comment or letter to the editor. Page charges for comments and letters are waived.

I. Papers on the History of Soil Science

Papers on the history of soil science that are recommended by the SSSA Council on the History of Soil Science will be published in *SSSA Journal* if approved by the editorial board following peer review.

J. Society Affairs

Business affairs of the Society and other items of interest and concern to members are published in the *SSSA Journal*.

K. Editorials

Editorials and guest editorials may be published in the *SSSA Journal* as the need arises and at the discretion of the Editor.

Conversion Factors for SI and non-SI Units

To convert Column 1 into Column 2, multiply by	Column 1 SI Unit	Column 2 non-SI Unit	To convert Column 2 into Column 1, multiply by
	Length		
0.621	kilometer, km (10^3 m)	mile, mi	1.609
1.094	meter, m	yard, yd	0.914
3.28	meter, m	foot, ft	0.304
1.0	micrometer, μm (10^{-6} m)	micron, μ	1.0
3.94×10^{-2}	millimeter, mm (10^{-3} m)	inch, in	25.4
10	nanometer, nm (10^{-9} m)	Angstrom, Å	0.1
	Area		
2.47	hectare, ha	acre	0.405
247	square kilometer, km^2 $(10^3\ m)^2$	acre	4.05×10^{-3}
0.386	square kilometer, km^2 $(10^3\ m)^2$	square mile, mi^2	2.590
2.47×10^{-4}	square meter, m^2	acre	4.05×10^3
10.76	square meter, m^2	square foot, ft^2	9.29×10^{-2}
1.55×10^{-3}	square millimeter, mm^2 $(10^{-3}\ m)^2$	square inch, in^2	645
	Volume		
9.73×10^{-3}	cubic meter, m^3	acre-inch	102.8
35.3	cubic meter, m^3	cubic foot, ft^3	2.83×10^{-2}
6.10×10^4	cubic meter, m^3	cubic inch, in^3	1.64×10^{-5}
2.84×10^{-2}	liter, L (10^{-3} m^3)	bushel, bu	35.24
1.057	liter, L (10^{-3} m^3)	quart (liquid), qt	0.946
3.53×10^{-2}	liter, L (10^{-3} m^3)	cubic foot, ft^3	28.3
0.265	liter, L (10^{-3} m^3)	gallon	3.78
33.78	liter, L (10^{-3} m^3)	ounce (fluid), oz	2.96×10^{-2}
2.11	liter, L (10^{-3} m^3)	pint (fluid), pt	0.473
	Mass		
2.20×10^{-3}	gram, g (10^{-3} kg)	pound, lb	454
3.52×10^{-2}	gram, g (10^{-3} kg)	ounce (avdp), oz	28.4
2.205	kilogram, kg	pound, lb	0.454
0.01	kilogram, kg	quintal (metric), q	100
1.10×10^{-3}	kilogram, kg	ton (2000 lb), ton	907
1.102	megagram, Mg (tonne)	ton (U.S.), ton	0.907
1.102	tonne, t	ton (U.S.), ton	0.907
	Yield and Rate		
0.893	kilogram per hectare, kg ha^{-1}	pound per acre, lb $acre^{-1}$	1.12
7.77×10^{-2}	kilogram per cubic meter, kg m^{-3}	pound per bushel, bu^{-1}	12.87
1.49×10^{-2}	kilogram per hectare, kg ha^{-1}	bushel per acre, 60 lb	67.19
1.59×10^{-2}	kilogram per hectare, kg ha^{-1}	bushel per acre, 56 lb	62.71
1.86×10^{-2}	kilogram per hectare, kg ha^{-1}	bushel per acre, 48 lb	53.75
0.107	liter per hectare, L ha^{-1}	gallon per acre	9.35
893	tonnes per hectare, t ha^{-1}	pound per acre, lb $acre^{-1}$	1.12×10^{-3}
893	megagram per hectare, Mg ha^{-1}	pound per acre, lb $acre^{-1}$	1.12×10^{-3}
0.446	megagram per hectare, Mg ha^{-1}	ton (2000 lb) per acre, ton $acre^{-1}$	2.24
2.24	meter per second, m s^{-1}	mile per hour	0.447
	Specific Surface		
10	square meter per kilogram, m^2 kg^{-1}	square centimeter per gram, cm^2 g^{-1}	0.1
1000	square meter per kilogram, m^2 kg^{-1}	square millimeter per gram, mm^2 g^{-1}	0.001
	Pressure		
9.90	megapascal, MPa (10^6 Pa)	atmosphere	0.101
10	megapascal, MPa (10^6 Pa)	bar	0.1
1.00	megagram per cubic meter, Mg m^{-3}	gram per cubic centimeter, g cm^{-3}	1.00
2.09×10^{-2}	pascal, Pa	pound per square foot, lb ft^{-2}	47.9
1.45×10^{-4}	pascal, Pa	pound per square inch, lb in^{-2}	6.90×10^3

(continued on next page)

Conversion Factors for SI and non-SI Units

To convert Column 1 into Column 2, multiply by	Column 1 SI Unit	Column 2 non-SI Unit	To convert Column 2 into Column 1, multiply by
	Temperature		
1.00 (K − 273)	Kelvin, K	Celsius, °C	1.00 (°C + 273)
(9/5 °C) + 32	Celsius, °C	Fahrenheit, °F	5/9 (°F − 32)
	Energy, Work, Quantity of Heat		
9.52×10^{-4}	joule, J	British thermal unit, Btu	1.05×10^{3}
0.239	joule, J	calorie, cal	4.19
10^{7}	joule, J	erg	10^{-7}
0.735	joule, J	foot-pound	1.36
2.387×10^{-5}	joule per square meter, J m^{-2}	calorie per square centimeter (langley)	4.19×10^{4}
10^{5}	newton, N	dyne	10^{-5}
1.43×10^{-3}	watt per square meter, W m^{-2}	calorie per square centimeter minute (irradiance), cal cm^{-2} min^{-1}	698
	Transpiration and Photosynthesis		
3.60×10^{-2}	milligram per square meter second, mg m^{-2} s^{-1}	gram per square decimeter hour, g dm^{-2} h^{-1}	27.8
5.56×10^{-3}	milligram (H_2O) per square meter second, mg m^{-2} s^{-1}	micromole (H_2O) per square centimeter second, μmol cm^{-2} s^{-1}	180
10^{-4}	milligram per square meter second, mg m^{-2} s^{-1}	milligram per square centimeter second, mg cm^{-2} s^{-1}	10^{4}
35.97	milligram per square meter second, mg m^{-2} s^{-1}	milligram per square decimeter hour, mg dm^{-2} h^{-1}	2.78×10^{-2}
	Plane Angle		
57.3	radian, rad	degrees (angle), °	1.75×10^{-2}
	Electrical Conductivity, Electricity, and Magnetism		
10	siemen per meter, S m^{-1}	millimho per centimeter, mmho cm^{-1}	0.1
10^{4}	tesla, T	gauss, G	10^{-4}
	Water Measurement		
9.73×10^{-3}	cubic meter, m^3	acre-inches, acre-in	102.8
9.81×10^{-3}	cubic meter per hour, m^3 h^{-1}	cubic feet per second, ft^3 s^{-1}	101.9
4.40	cubic meter per hour, m^3 h^{-1}	U.S. gallons per minute, gal min^{-1}	0.227
8.11	hectare-meters, ha-m	acre-feet, acre-ft	0.123
97.28	hectare-meters, ha-m	acre-inches, acre-in	1.03×10^{-2}
8.1×10^{-2}	hectare-centimeters, ha-cm	acre-feet, acre-ft	12.33
	Concentrations		
1	centimole per kilogram, cmol kg^{-1}	milliequivalents per 100 grams, meq 100 g^{-1}	1
0.1	gram per kilogram, g kg^{-1}	percent, %	10
1	milligram per kilogram, mg kg^{-1}	parts per million, ppm	1
	Radioactivity		
2.7×10^{-11}	becquerel, Bq	curie, Ci	3.7×10^{10}
2.7×10^{-2}	becquerel per kilogram, Bq kg^{-1}	picocurie per gram, pCi g^{-1}	37
100	gray, Gy (absorbed dose)	rad, rd	0.01
100	sievert, Sv (equivalent dose)	rem (roentgen equivalent man)	0.01
	Plant Nutrient Conversion		
	Elemental	***Oxide***	
2.29	P	P_2O_5	0.437
1.20	K	K_2O	0.830
1.39	Ca	CaO	0.715
1.66	Mg	MgO	0.602

Suggestions for Contributors to the *Soil Science Society of America Journal*

General Requirements

Contributions to the *SSSA Journal* may be (i) papers and notes on original research; and (ii) "Comments and Letters to the Editor" containing (*a*) critical comments on papers published in one of the Society outlets or elsewhere, (*b*) editorial comment or comments by Society officers, or (*c*) personal comments on matters having to do with soil science. Notes are not to exceed two printed pages; Letters to the Editor, one printed page. Contributions need not have been presented at annual meetings. Original research findings are interpreted to mean the outcome of scholarly inquiry, investigation, modeling, or experimentation having as an objective the revision of existing concepts, the development of new concepts, or the development of new or improved techniques in some phase of soil science. Authors are encouraged to test modeling results with measurements or published data. Short, critical reviews or essays on timely subjects, upon invitation by the Editorial Board, may be published on a limited basis. See SSSA Publication Policy (Soil Sci. Soc. Am. J. 63:1–3, 1999).

Membership in the Society is not a requirement for publication in the *SSSA Journal*; however, nonmembers will be charged for the first six published pages of a manuscript. To qualify for member rates, at least one author must be an active, emeritus, graduate student, or undergraduate student member of SSSA, CSSA, or ASA on the date the manuscript is accepted for publication.

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SOIL SCIENCE SOCIETY OF AMERICA
JOURNAL

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HISTORY OF SOIL SCIENCE

Who Invented the Tensiometer?

Dani Or*

ABSTRACT

The invention of the tensiometer for measurement of soil water matric potential is commonly attributed to Willard Gardner, with the first robust design for field applications attributed to Lorenzo A. Richards during the early 1920s. However, evidence shows that the original design was proposed by Burton E. Livingston as early as 1908 (perhaps earlier) with advanced implementation of similar concepts for "measuring the capillary lift of soils" by Lynde and Dupre in 1913.

ONE OF THE MOST USEFUL DEVICES for monitoring soil water status is the tensiometer. It consists of a porous cup (usually made of ceramic with very fine pores) connected to a vacuum gauge (mechanical or electronic transducer) through a rigid water-filled tube (Fig. 1). The porous cup is placed in intimate contact with the bulk soil at the depth of measurement. When the matric potential of the soil is lower (more negative) than the equivalent pressure inside the tensiometer cup, water moves from the tensiometer along a potential energy gradient to the soil through the saturated porous cup, thereby creating suction sensed by the gauge. Water flow into the soil continues until equilibrium is reached and the suction inside the tensiometer equals the soil matric potential (i.e., when the driving force dissipates). When the soil is wetted, flow may occur in the reverse direction; that is, soil water enters the tensiometer until a new equilibrium is attained.

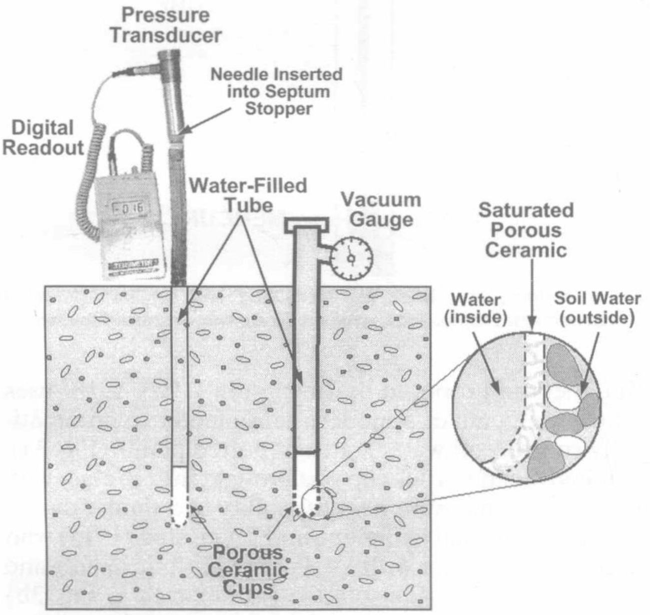

Fig. 1. Modern tensiometer designs.

In their textbook *Soil Physics*, Marshall et al. (1996) attributed the introduction of the tensiometer to Richards (1928, whose original drawing is shown in Fig. 2a). Cassel and Klute (1986) attributed the first complete description of the tensiometer to an abstract published

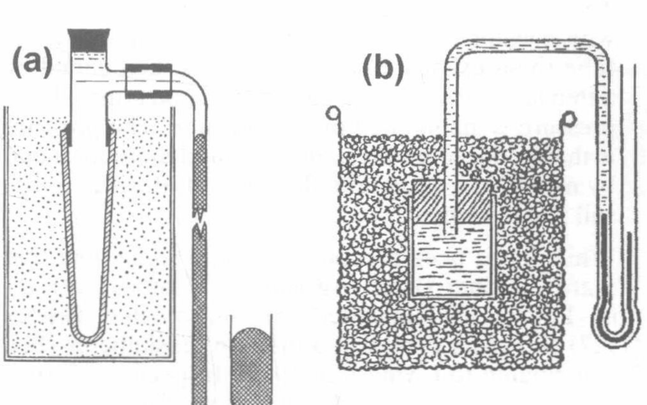

Fig. 2. (a) Richards' (1928) tensiometer design. (b) Haines' (1927) design attributed to Livingston (1918).

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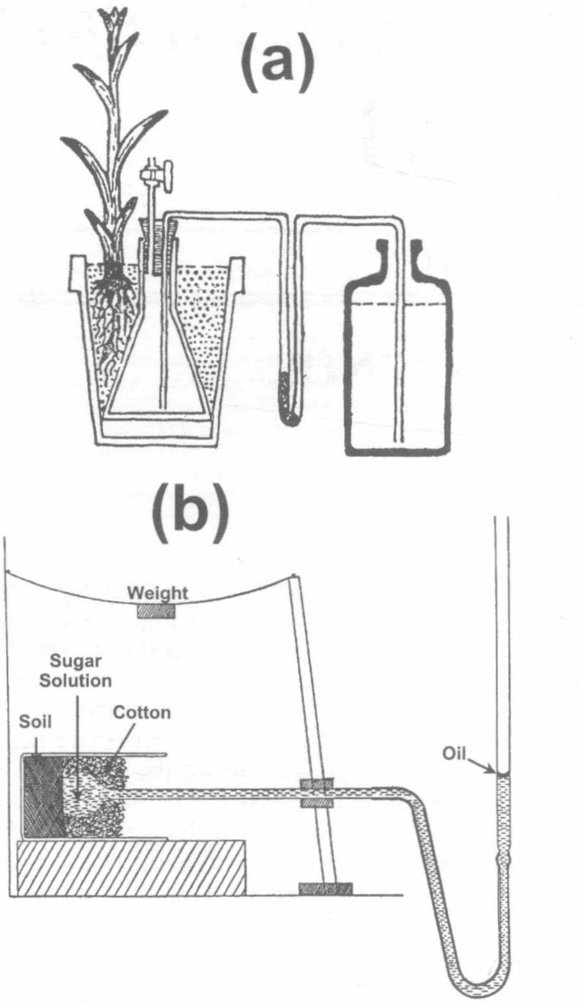

Fig. 3. (a) Livingston's (1908, 1918) auto-irrigator for maintaining constant matric potential in potted plant root zone. (b) Tensiometer–osmometer designed by Pulling and Livingston (1915) to measure the "water supplying power of the soil." (Notation of original figure was enhanced for clarity).

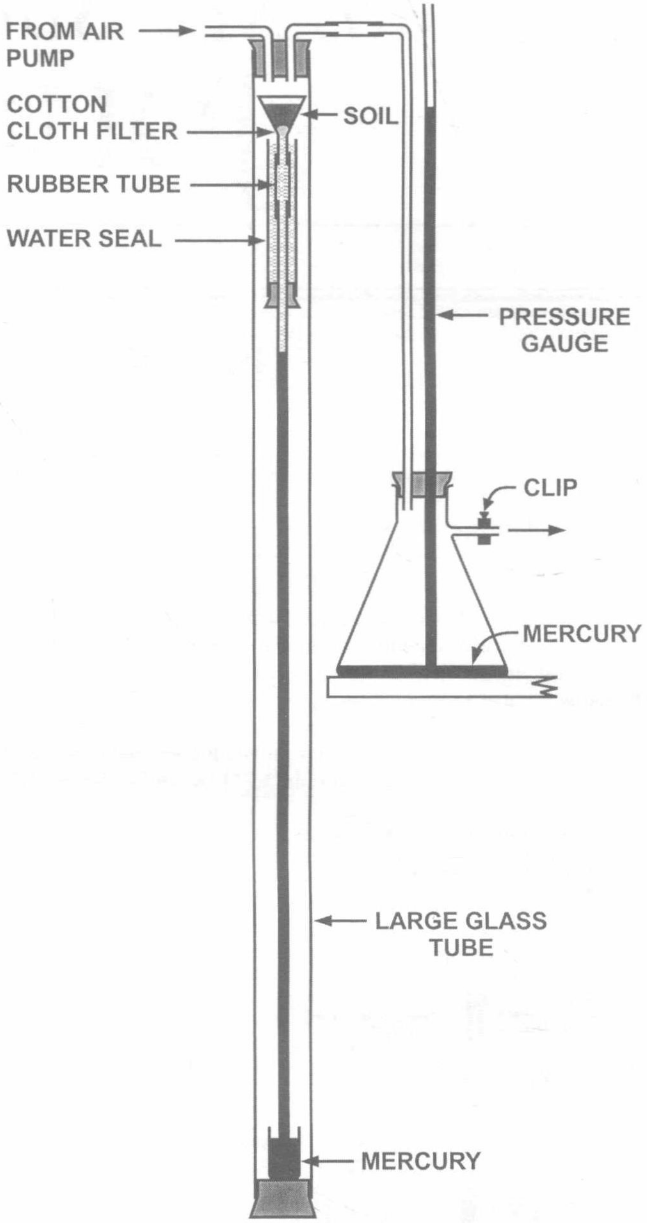

Fig. 4. A hanging column for measuring soil capillary potential (Lynde and Dupre, 1913; original figure was redrawn for clarity).

by Gardner et al. (1922). The description in Gardner's abstract reads:

> The apparatus used consists of a porous cup closed with a water-tight joint and connected through a tall tube to an exhaust pump. The cup is surrounded by a thin layer of soil in the outer vessel and atmospheric pressure is maintained on the soil side. The pressure is then reduced on the water side and measured, and by means of a glass tube the amount of water in the soil is determined.

While it has been accepted for quite some time that Willard Gardner (Utah Agricultural Experiment Station, Logan, UT) invented the tensiometer, Haines (1927) showed a design of a modern tensiometer (Fig. 2b) attributed to Livingston (1918). Inspection of work published by Livingston (1908, 1918) and Livingston and Hawkins (1915) convincingly shows that the tensiometer was invented more than a decade before the description by Gardner et al. (1922).

Thus, the earliest account of a tensiometer or a tensiometer-like device was reported by Livingston (1908). The method proposed by Livingston (1908, 1918) uses all the elements of a modern tensiometer to automatically control soil water status of potted plants (Fig. 3a). A liquid-filled porous cup was brought into contact with the soil. The measurement capability of a similar device was demonstrated by Pulling and Livingston (1915) who used an osmometer with a collodion osmotic membrane backed by sugar cane solution (as depicted in Fig. 3b) to measure the "water supplying power of the soil."

A related early development was reported by Lynde and Dupre (1913) who described experimental methods for "measuring the capillary lift of soils." The basic design is that of a hanging water column as shown in Fig. 4 (note that the experimental setup was capable of measuring capillary pressures in soils for ambient pressures different—greater or lower—than atmospheric).

In summary, Livingston (1908) appears to be the first to have implemented a tensiometer for measurement and control of soil matric potential. The most likely precursor for this invention was the so-called porous cup atmometer (Livingston and Hawkins, 1915, p. 11). These authors cited work by Babinet (1848), who named the device atmidoscope. The analogy and the process were explained by Livingston and Hawkins (1915): "In the porous cup atmometer evaporation removes water from the system. In the auto-irrigator the 'capillary' attraction of the surrounding soil brings about the same result. As water passes from the cup to soil it automatically distributes itself so as to tend towards equilibrium throughout the soil mass."

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DIVISION S-1—SOIL PHYSICS

Simultaneous Measurement of Soil Penetration Resistance and Water Content with a Combined Penetrometer–TDR Moisture Probe

Carlos Manoel Pedro Vaz and Jan W. Hopmans*

ABSTRACT

Soil mechanical impedance affects root growth and water flow, and controls nutrient and contaminant transport below the rooting zone. Among the soil parameters affecting soil strength, soil water content and bulk density are the most significant. However, field water content changes both spatially and temporally, limiting the application of cone penetrometers as an indicator of soil strength. Considering the presence of large water content variations within a soil profile and across a field and the large influence of water content on soil strength, there is need for a combined penetrometer–moisture probe to provide simultaneous field water content and soil resistance measurements. Such a probe was developed, which uses the time domain reflectometry (TDR) technique to determine water content and its influence on soil penetration resistance. The coiled TDR moisture probe consists of two parallel copper wires, each 0.8 mm in diameter and 30 cm long, coiled around a 5-cm-long polyvinyl chloride (PVC) core with a 3-mm separation between wires. Calibration curves relating the soil bulk dielectric constant measured by the coiled probe to water content were obtained in the laboratory for a Columbia fine sand loam (coarse-loamy, mixed, superactive, nonacid, thermic Oxyaquic Xerofluvent), a Yolo silt clay loam (fine-silty, mixed, nonacid, thermic Typic Xerorthent), and washed sand, and data were analyzed based on a mixing model approach. Subsequently, field experiments were conducted to measure simultaneously the penetration resistance (PR) and water content along a soil profile. Results showed a detailed water content profile with excellent correlation with the gravimetric method, whereas the depth distribution of PR was similar to that of dry bulk density as determined from soil cores.

SOIL MECHANICAL STRENGTH is an important soil parameter that affects root growth and water movement and controls nutrient and contaminant transport below the rooting zone. The most common way to assess soil strength is by using a soil penetrometer, which characterizes the force needed to drive a cone of specific size into the soil (Bradford, 1986). The measured PR depends on such soil properties as bulk density, water content and potential, texture, aggregation, cementation, and mineralogy.

Soil scientists have related changes in PR as caused by tillage, traffic, or soil genetic pans to root growth, crop yields, and soil physical properties. For example, correlation between PR and crop root growth and water and nutrient exploration have been obtained (Stelluti et al., 1998), and cone penetrometers have been used extensively in soil science studies to identify natural and induced compacted layers (Henderson, 1989) or to predict related soil properties (Ayers and Bowen, 1987).

Among the soil parameters that affect PR, soil water content and bulk density are the most significant (Vazquez et al., 1991). For example, Stitt et al. (1982) conducted a comprehensive study of factors affecting PR in coarse-textured soils in the Atlantic Coastal Plain, and used stepwise regression to relate mechanical impedance to various measured soil properties. The highest correlation coefficients were found for a regression model that included soil water content, soil particle roughness and bulk soil density. Shaw et al. (1942) concluded that soil moisture is the dominant factor influencing the force required to push a penetrometer into the soil, with PR increasing as the moisture content decreased. In an experimental study by Henderson et al. (1988) it was found that PR was only slightly affected with a decrease of soil water content to ≈70% of field capacity. However, the PR increased exponentially with a further reduction of the water content of the sandy soil. This study showed that PR increased with an increase of bulk density across the whole measured water content range. However, because soil moisture varies both spatially and temporally and is only one of the soil variables related to PR, the utility of using PR to determine compaction effects is marginal. Moreover, interpretation of penetrometer data is difficult because water content or density measurements can generally not be taken at the exact same spatial location as the penetration resistance measurement.

Considering the strong dependence of PR on soil water content within a soil profile and across a field, it would be beneficial if both soil water content and soil resistance could be measured simultaneously at the same location and depth with a single probe. Among available techniques for soil water content measurements, TDR is the most attractive. Advantages of TDR over other soil water content measurement techniques include (i) potential for variable measurement volume size using different probe sizes and geometry, (ii) the use of the same probe for both laboratory and field measurements, (iii) small influence of dissolved solutes on the TDR moisture measurement within a low salinity range, (iv) its potential for automatic data acquisition

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Abbreviations: PR, penetration resistance; PVC, polyvinyl chloride; TDR, time domain reflectometry.

and multiplexing, and (v) that it does not pose a radiation hazard.

Most commercial TDR equipment uses standard waveguides or probes with a usual length of 15 to 30 cm. The soil water content value is obtained from calibration curves using the travel time of an electromagnetic wave along the waveguide to determine the bulk dielectric constant of the soil (Topp et al., 1980). A minimum probe length is controlled by the rise time of the electromagnetic square wave reflected at the beginning and end of the TDR probe (Nissen et al., 1998). Petersen at al. (1995) examined the importance of probe length and diameter, distance between wave guides, and horizontal installation depth. They obtained excellent waveforms using a 5-cm probe in a coarse sandy soil with a water content of 0.21 $cm^3\ cm^{-3}$. Kelly et al. (1995) obtained an accuracy of 0.035 $cm^3\ cm^{-3}$ using TDR probes as short as 2.5 cm and a high-band width TDR system of 20 MHz. Amato and Ritchie (1995) experimented with short probes ranging in length from 1 to 15 cm. They concluded that at water content values of 0.07 $cm^3\ cm^{-3}$ with travel times larger than 100 ps, the error in the water content was less than three volume percent. However, for water content measurements in drier soils with shorter travel times, errors were larger than 4 to 5%. Malicki et al. (1992) and Sri Ranjan and Domytrak (1997) described successfully the use of TDR miniprobes (5 cm long) for a clay loam soil.

Selker et al. (1993) introduced a serpentine type surface probe (10 by 10 cm) by imbedding the conductor and ground wires of the TDR probe within an acrylic plate, enabling miniaturization of TDR probes for high spatial resolution measurements. For the coiled probe developed by Nissen et al. (1998) the conductor wire was guided around a cylindrical PVC rod with four straight ground wires along the PVC rod. Their TDR probe allowed a reduction in probe length of a factor of five without a loss in sensitivity. To avoid short-circuiting, the conductor and ground wires were lacquer-coated. In both designs, the increased conductor wire lengths ensured long enough travel times for accurate water content measurements despite the smaller measured bulk soil volume. Both designs (serpentine and coil) are innovative compared with the traditional two, three, or four rod probes and bring many new TDR applications.

The concept of a combined measurement of penetration resistance and water content was previously presented (Ward, 1994; Young et al., 1998; Adams et al., 1998; Newman and Hummel, 1999; Vaz et al., 1999), but to date details regarding construction and calibration for different soils has been limited. For that reason, the objective of this work was to design, construct, and evaluate a coiled TDR probe to be used in combination with a cone penetrometer to determine water content and penetration resistance along a soil profile in a field setting. After analysis of the testing in the laboratory, the combined penetrometer–TDR soil moisture probe measurement results for the field are presented.

MATERIALS AND METHODS

Coiled and Conventional TDR Probe Design

The presented coiled TDR probe combines the advantages of both the coil (Nissen et al., 1998) and serpentine (Selker et al., 1993) designs, with the TDR integrated into the cone penetrometer. The basic configuration of this coiled probe (Fig. 1a and 1b) consists of two parallel copper wires (ground

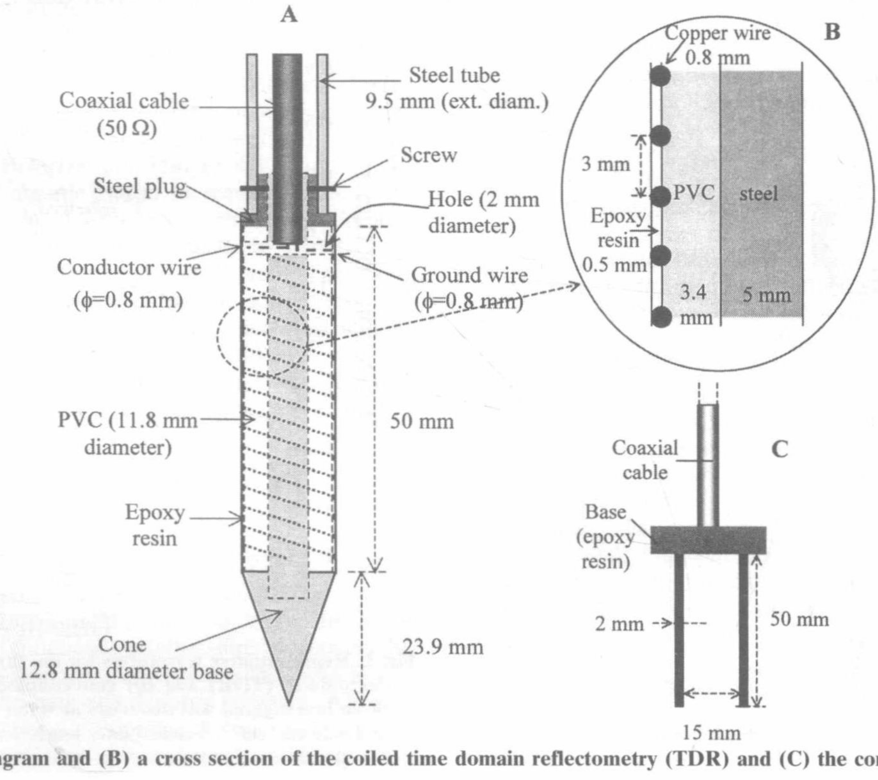

Fig. 1. Detailed (A) diagram and (B) a cross section of the coiled time domain reflectometry (TDR) and (C) the conventional TDR probe.

and conductor wire), each 0.8 mm in diameter and 30 cm long, coiled around a 5-cm-long PVC core, with a 3-mm separation distance between the two wires. The coil is constructed at the bottom of the penetrometer rod, immediately above the cone of the penetrometer. A 2.5-m-long 50 Ω coaxial cable is passed through the hollow steel shaft of the penetrometer probe and connected to a cable tester (Tektronix 1502C, Tektronix, Beaverton, OR). Both copper wires were soldered to the corresponding conductor and ground of the coaxial cable in two opposing 2-mm access holes, right above the coil, as shown in Fig. 1a. The spaces between the wires of the coil and the two access holes were filled with an epoxy resin (2-Ton crystal clear epoxy, Devcon, Riviera Beach, FL) and smoothed to avoid the creation of air spaces between the wires during soil insertion. However, probe–soil contact is also largely affected by the probe operator as straight vertical insertion is required. Figure 2 shows the details of the combined TDR–cone penetrometer probe. Cone and probing rod sizes satisfy the American Society of Agricultural Engineers Standards (American Society of Agricultural Engineers, 1994).

A 5-cm-long conventional TDR probe (illustrated in Fig. 1c) was constructed to independently measure the bulk soil dielectric constant of soil cores used in the calibration of the coiled probe. The two parallel brass rods (2-mm diam. and 15 mm apart) were soldered directly to a 50 Ω coaxial cable mounted in an epoxy resin base as shown in Fig. 1c.

Laboratory Calibration

The waveform or trace is transferred from the cable tester to a personal computer through the RS232 serial port and analyzed. The trace (Fig. 3a and 3b) is a visualization of the amplitude of a reflected pulsed electromagnetic wave as a function of propagation or travel time along the TDR probe. The trace can be regarded as a signature of the physical status of the soil, and it can be shown that knowledge of the travel time is sufficient to determine the bulk material dielectric constant of the soil (Topp et al., 1980). Travel times and bulk dielectric constant are determined by identification of the first and second reflection at the beginning and end of both TDR probe types. The procedural steps used to identify these reflec-

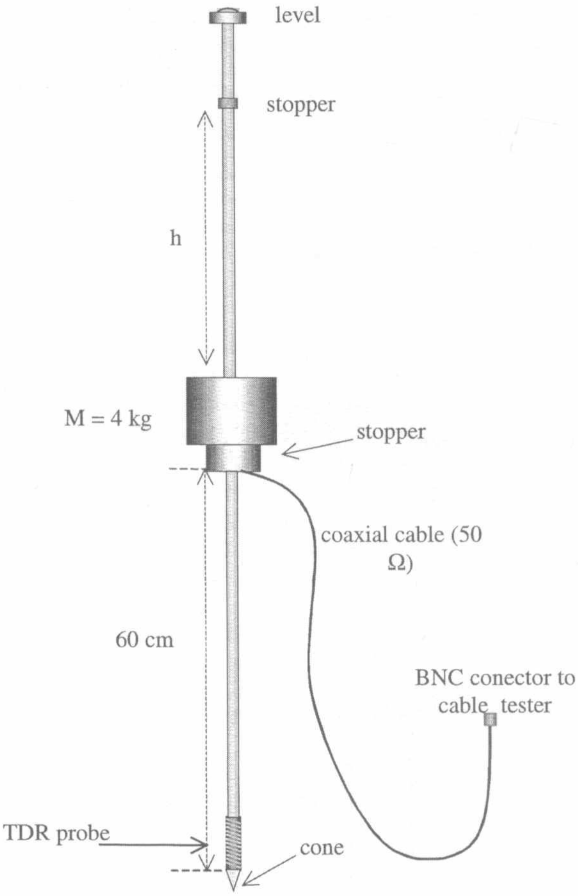

Fig. 2. Combined coiled time domain reflectometry (TDR)–cone penetrometer probe.

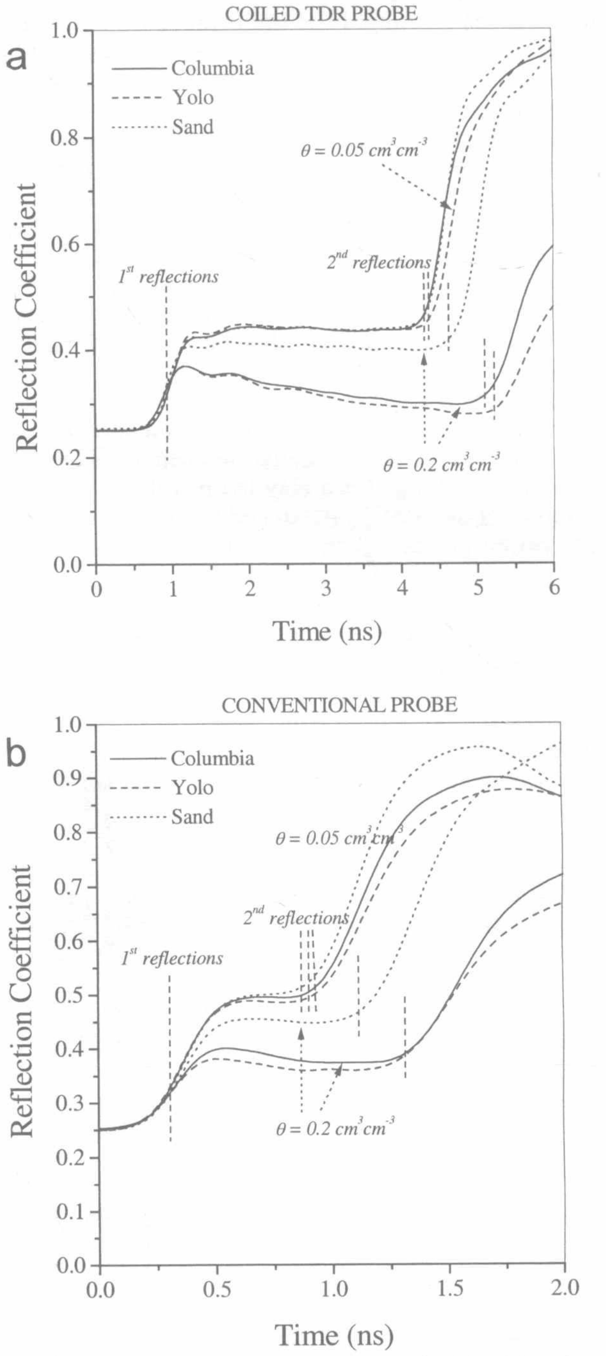

Fig. 3. Representative waveforms for the (a) coiled time domain reflectometry (TDR) and (b) conventional probe designs for the three investigated soil materials at water contents values of 0.05 and 0.20 cm^3 cm^{-3}. Vertical lines mark the first and second reflection points.