SOIL PHYSICS AT WASHINGTON STATE UNIVERSITY[1]

Walter H. Gardner[2]

An informal beginning of soil physics at what now is Washington State University must coincide with the beginning of instruction in agriculture in 1892, three years after Washington statehood. Throughout agricultural history physical properties of soil, the domain of soil physics, have received almost the first consideration in cultivation of soil to produce crops. Furthermore, whatever the researcher working with soil is called his use of physics is a fundamental necessity in its study. The movement of water into soil and its uptake by roots, movement of chemical elements in the soil, their adsorption on the clay complex and the physical properties they influence, the energy cycle in the soil-plant-atmosphere continuum, all require the application of physics for their understanding. Probably more than any other of the fundamental science disciplines, physics is basic to agriculture.

The first reference to soil physics in the college history is the hiring of C. C. Thom in 1910 as an Assistant Professor of Agriculture with the designation of "soil physicist". No reference to publications by Thom appear in early editions of "Bibliography of Soils", but he is the senior author of Washington Agricultural Experiment Station

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Bulletin 146, 1917, "Factors influencing Water Requirements of Plants" with H. F. Holtz, published five years after he left Washington State. Thom's major interests may not have been in soil physics inasmuch as he has publications in the late 1930's in the areas of soil microbiology or plant pathology. Thom resigned in 1912 and appears to have been replaced in 1914 by Henry F. Holtz whose title is listed as "Assistant Soil Physicist". Holtz remained until 1919 but, as with Thom, his only publication which could be identified as in soil physics appears to be the bulletin cited above. The records show that F. J. Sievers, listed as a "soil physicist", came as "Head of Soils Department" in 1917, remaining here until 1927 when he resigned. Again, no publications have been found. Evidently in 1917 there were two departments in the area which later became "agronomy" inasmuch as the records show P. J. White as "Acting Head, Department of Agriculture" and "Head, Department of Farm Crops".

There appears to have been no soil physicist at the college after Sievers left in 1927 until the coming of J. R. McHenry as "Assistant Soil Physicist" in 1947. He left in 1949. McHenry's work here was primarily in clay mineralogy. Assisting him in clay mineralogy beginning in 1948 on a part-time assignment was Robert McCreery who received a PhD and left in 1952.

Glen M. Horner, who studied soil physics with L. D. Baver at Ohio State, came to Washington State in 1936 with the USDA cooperative soil erosion program. Horner worked

cooperatively with Washington State people in agronomy and agricultural engineering on erosion problems until he left for a foreign assignment in 1965. Another USDA soil physicist, Ross Leamer, was at the Irrigation Experiment Station in Prosser from 1948 to 1951. Later in 1951 J. S. Robins (ASA Fellow, 1971) replaced Leamer at Prosser, leaving there in 1956 to become USDA Research Investigations Leader stationed at Ft. Collins, Colorado until 1961 when he moved to Boise, Idaho as USDA-ARS Branch Chief. He returned to Prosser as Superintendent of WSU's Agricultural Research and Extension Center in 1965 and moved to Pullman as Director of the Washington Agricultural Research Center in 1967. After spending from 1970 to 1973 in Washington, DC as Associate Administrator for the CSRS he returned again to Pullman as Dean of the College of Agriculture which position he held until 1981 when he left for a position in Washington, DC as an advisor to AID and in 1982 as First Line Officer, Director for Agriculture, USAID.

When Glenn Horner left WSU for a foreign assignment in 1964 soil physicists, Leonard Johnson (who left in 1970) and Robert I. Papendick (ASA Fellow, 1977) in 1965, took over responsibility for the USDA erosion research at Pullman. Both of these people participated extensively in the graduate soil physics program at WSU, Papendick chairing numerous graduate committees. [The USDA Erosion Station work is covered elsewhere in this history.]

It should be noted that L. T. Kardos (1910-1985) came

to the college in 1936 as "Assistant in Soils". Kardos received a PhD in soil chemistry from Rutgers in 1937. He remained until 1943 when he went to the University of New Hampshire and in 1954 to the Pennsylvania State University as a soil physicist. At Washington State Kardos had several publications in soil chemistry and genetic classification and two publications with strong relations to soil physics: "Factors contributing to landslides in the Palouse region" (with P. I. Vlasoff and S. N. Twiss (1943) 1944 Proc. Soil Sci. Soc. Amer. 8:437-440) and "Lysimeter studies with cultivated and virgin soils under subhumid rainfall conditions" (1948, covering work done at Washington State, Soil Sci. 65:367-381.) Soil physics received some attention of other soils faculty in the same period. L. C. Wheeting published a paper in 1936 involving soil physics, "Static friction measurements in the study of soil moisture relationships" (Soil Sci. 41:1-11), and two others in 1940-41, "The significance of natural erosion" (N.W. Sci. 14:11-13) and "Fertilizer placement under irrigation in Washington" (with C. E. Nelson of the Irrigation Experiment Station as senior author, Jour. Am. Soc. of Agron. 33:105-114).

Graduate work in soil physics at Washington State began under McHenry in 1949 with Raymond A. Gilkeson who completed work for a Master's degree under McHenry's successor, Walter H. Gardner, in 1951. Gardner (ASA Fellow, 1966) came to Washington State in the spring of 1950 with his PhD from what now is Utah State University. As at most other land-

grant universities, post baccalaureate education in agriculture expanded rapidly after World War II and graduate work in soil physics became a significant part of the program at Washington State. A graduate course in soil physics was begun in 1951 and students from other departments such as, plant physiology, plant pathology, horticulture, forestry, agricultural engineering, and physics began taking course work in soil physics. Gardner served on graduate committees for numerous students in a number of departmental programs and presented seminars for related departments showing the importance of physical principles, particularly those related to energy status of water in soil and plant tissues. Introduction of such physics into research work in other departmental research programs, including zoological investigations, was greatly expanded later by Gaylon S. Campbell who joined the faculty in 1968. Gardner served as president of the WSU Chapter of Sigma Xi in 1960, as editor-in-chief, Soil Science Society of America Proceedings, 1966-69, president of the Western Society of Soil Science in 1967, Soil Science Society of America in 1983-84. Two former WSU PhD students in soil physics chaired SSSA Divisions the same year Gardner was president: A. Hayden Ferguson (ASA Fellow, 1981), Division S-1, Soil Physics, and David E. Miller, Division S-6, Soil and Water Management and Conservation. At the same time another WSU soil physicist, Stephen L. Rawlins (ASA Fellow, 1976), became the staff soil physicist for the USDA-ARS in

Washington, DC. Gardner served as president of the American Association for the Advancement of Science, Pacific Division, in 1984. He is an author, with L. D. Baver and W. R. Gardner of the text book, Soil Physics. As a diversion from soil physics in 1960 he was a member of the Honors Council which created the University Honors Program, serving as associate chairman in the operation of the program for its first two years. He received a Guggenheim Fellowship for study in The Netherlands in 1964-65 and served with the International Atomic Energy Agency in Vienna in 1971-72.

Three Gardner publications of soil physics historical interest are a history of the synthetic soil conditioning movement, "Use of Synthetic Soil Conditioners in the 1950's and some Implications to their Further Development" (Mededelingen Landbouwwetenschappen State University, Ghent, Belgium, 1972, 37,3:1046-1061), Bicentennial address, Division S-1, SSSA, "Historical Highlights in American Soil Physics, 1776-1976" (SSSA Proc. 41:221-229, 1977), and "Early Soil Physics into the Mid-20th Century", Advances in Soil Science (Springer-Verlag, NY, in press). A collection of historical information on soil physics and soil science is avaliable at WSU.

David E. Miller, during the final stages of dissertation completion in soil physics at WSU, in 1955 joined the USDA staff at Prosser where he engaged in research related to crop water use and irrigation management, publishing numerous research papers. He also participated in the graduate program in soil physics at WSU,

being on a number of graduate committees and chairing the M.S. committee for Babiker Abdalla Ibrahim in 1985. An Hang, WSU, joined Miller in irrigation research at Prosser in 1978.

Soil physics experienced a significant increase in activity in 1968 when Gaylon S. Campbell (ASA Fellow, 1984), who received his PhD degree at Washington State, was hired to teach environmental biophysics in the newly created Environmental Science Program at WSU and to carry on research in their Agricultural Experiment Station. Immediately following his appointment Campbell was called to serve a two-year active duty assignment with the Army Signal Corps where he worked in micrometeorology research. Gardner taught the new class in environmental biophysics in his absence. Campbell received his bachelor's degree in physics and a master's degree in soil physics at Utah State University working with Sterling Taylor. Campbell's research has involved soil physics generally but has emphasized the energy status in the soil-plant-atmosphere continuum. He is the author of a text, "Environmental Biophysics". He spent two years, 1976-77 and 1984-85, at the University of Nottingham in England working with noted micrometeorologist, J. L. Monteith. Shortly before Gardner's retirement in 1982 Campbell took over the advanced graduate course in soil physics. Campbell was an early proponent of computer use and early in the 1970's he began to apply computer modeling to the solution of rather

difficult problems in soil water flow. His interest in modeling later was extended to many problems, including fertilizer use and crop production. Colleagues in the department and elsewhere on the campus came to seek his help on computer use and modeling. He introduced the secretarial use of computer word processing in the department well ahead of other University offices. A text book for use in advanced soil physics classes, "Soil Physics with Basic: Transport Models for Soil-Plant Systems", is in press currently. Gardner continued part-time for the fall 1982 term to teach the first course in soil physics and in 1983 David Mulla was hired to teach this course and for research in soil physics. Mulla came to the university from Purdue University where he worked with Phillip F. Low, a noted soil physical-chemist, and with soil physicist, John H. Cushman.

Agricultural research in the post World War II era was greatly expanded with the creation of a federal program under the USDA referred to as "Regional Research". Regional research committees and technical committees to carry out research were formed throughout the country with eleven states cooperating in the west. Soil physics at Washington State was a participant from the start, first in a project on irrigation and drainage, W-9. Gardner was a member of this committee, as well as a long-time member and 1963 chairman of the overall Western Soil and Water Research Committee. The W-9 program at WSU was cooperative with WSU's Department of Agricultural Engineering, with Aldert Molenaar until his retirement followed by Max C. Jensen.

Soil chemist colleague, Dawson Moodie, was much involved in early regional research and replaced Gardner in the Western Soil and Water Research Committee when Moodie became chairman of the department in 1968. Soil physics at WSU was involved with and received material financial support from several of these technical committees. The committees were revised at five-year intervals and WSU continues its involvement at the present time in some of the committees. It is instructive to note that by means of the technical research committees each participating university (USDA research groups also were involved) was able to secure the benefit of relevant research at neighboring universities and, in effect, to enlarge its own research staff. The committees meet annually to share research findings and to plan future research work. The expansion of research applications in agriculture and savings through elimination of unneeded duplication of research efforts at every lands-grant research university has been of monumental significance in agricultural research. Washington State soil physicists have been involved in the following Regional Research Technical Committees:

W-9, 1949-54, Irrigation and Soil Management Studies Including Drainage, Salinity, and Fertilization. (Cooperatively with the Department of Agricultural Engineering)

W-29, 1954-59, Soil-Water-Plant Relationships Under Irrigation.

W-30, 1954-59, Measurement, Evaluation, and Modification of Soil Structure (informally).

W-66, 1959-64, Structural Stability of Soil (informally).

W-67, 1959-64, Soil Moisture - Plant Growth Relationships.

W-68, 1959-64, Water Movement in Soil.

W-67, 1964-69, Water-Soil Plant Relations

W-68, 1964-69, Prediction of Water Movement in Soils of Arid and Semi-Arid Regions.

W-67, 1969-74, Quantification of Water-Soil-Plant Relations for Efficient Water Use.

W-68, 1969-74, Measurement, Prediction, and Control of Soil Water Movement in Arid and Semi-Arid Soils.

W-67, 1974-79, Application of Information on Water-Soil-Plant Relations to Use and Conservation of Water.

W-68, 1974-79, Soil Water and Its Management in the Field.

W-128, 1974-79, Trickle Irrigation (informally).

W-154, 1979-84, Crop Yield Potential as Affected by the Rhizosphere, Soil, and Other Environmental Factors.

W-155, 1979-84 Soil Water and Properties, Spatial Variability and Implications in Soil Management.

W-154, 1984-89 Crop Productivity as Limited by the Rhizosphere and by Water and Nutrient Use Efficiencies.

W-155, 1984-89 Characterization and Management of Soil Water and Solutes in Field Soils.

As would be expected with expansion of research and the development of an extensive graduate program, numerous publications in soil physics were forthcoming. The coming of synthetic soil conditioners in the early 50's created considerable excitement here as elsewhere in the country and WSU became involved in research on soil conditioning with membership on a national task force. Considerable local interest existed and the department responded to numerous

farmer and farm group requests for information on how this might bring about better control of soil erosion in the Palouse. J. C. Engibous, who became department chairman on the death of Dawson Moodie in 1970, visited the campus more than once as a technical representative for Monsanto Chemical which company introduced the first synthetic soil conditioner known as VAMA (vinyl acetate malaeic acid).

Washington State pioneered in the use of radiation methods for the measurement of soil bulk density and water content and developed the much-used laboratory method for concurrent measurement of bulk density and water content using gamma radiation from two energy sources, Americium-241 and Cesium-137. Pioneering work also was done on psychrometric methods for measuring the energy status of water in soil and in plant tissues. Much of the impetus for this work came with Campbell, who had worked in this area with Taylor at Utah State University, when he became a WSU graduate student. It is of some interest to note that the first soil psychrometers sold to research workers were made in the WSU soil physics laboratory by a time-slip employee whose time was paid for by the purchaser. Orders snow-balled and to meet the demand Dr. Campbell interested his brother, Eric, a student in physics at Utah State University, in making and selling soil psychrometers to help pay for his education. Eric could not keep up with orders and finally sold out to Wescor Incorporated, hiring himself to the company as a part-time expert. Later, with Dr. Campbell as an advisor and other brothers, a new company,

Campbell Scientific, was formed. It is of interest to note that the new company developed a dew-point method for measuring soil water potential and a medical osmometer, the latter instrument becoming the major tool now used in this medical application of what, originally was a soil instrument.

Another development with appreciable educational significance carried out by soil physicists at WSU has been the creation in 1960 of a time-lapse motion picture, "Water Movement in Soil". More than 500 copies of this film, handled by the Agronomy Club (later the Crops and Soils Club and now the Agronomy and Soils Club), are in use throughout the world for teaching principles of water flow. More than 20 thousand copies of a reprint of a popular publication, "Water Movement in Soil", by Gardner and published in CROPS AND SOILS (1962, revised in '68 and 79) by the American Society of Agronomy, which describes the film have been sold.

A number of visiting scientists have spent from several months to a year working with WSU soil physicists. Among them are Ben Zur from Israel, 1961-62; Sam J. Yang from Taiwan, 1969-71; Paul Benecke from the University of Gottingen, Hannover-Munden, West Germany, summer 1969; Isaac Shainberg. Israel, summer 1973 (with the soil chemists); Robert McDole, University of Idaho, 1974-75; John W. Cary, USDA-ARS, Kimberly, Idaho; 1976-77; Marcel Fuchs, 1974-75; Alfred Cass from South Africa, 1980-81.

The record of WSU graduate students in soil physics, with titles of their theses, which follows constitutes an indication of some of the post-World War II research work in soil physics (the major professor also is indicated):

Raymond A. Gilkeson, MS 1951 (Gardner). Moisture Conditions Under Fallow in the Wheat Area of Eastern Washington.

Paul P. Rowe, MS 1952 (Gardner). Moisture Movement in Furrow Irrigation.

_____ PhD 1960 (Gardner). An Equation for Unsaturated Flow Based Upon the Darcy Equation and an Analogy of the Poiseuille Equation.

Glen H. Cannell, PhD 1955 (Gardner). Freezing-Point Depressions in Sands, Soils and Synthetic Materials.

Samir R. Nagmoush, MS 1956 (Gardner). Effect of Source Pressure, Initial Moisture Content and Dimensions of Flow in Infiltration.

Stephen L. Rawlins, MS 1956 (Gardner). Soil Aggregate Stability Measurements and Electron Microscope Observations of Freeze-Dried Conditioner-Treated Soil Materials.

_____ PhD 1961 (Gardner). A Theoretical and Experimental Examination of the Validity of Diffusion Analyses as Applied to Unsaturated Flow of Soil Water.

A. Hayden Ferguson, MS 1956 (Gardner). Soil Conditioning Properties of an Ammonium Lignin Sulfonate.

_____ PhD 1959 (Gardner). Movement of Soil Water as Inferred from Moisture Content Measurements by Gamma Ray Absorption.

David E. Miller, PhD 1959 (Gardner). Effect of Profile Stratification and Other Factors on Water Infiltration.

Shamus Uddin Butt, MS 1961 (Gardner). Measurement of Water Infiltration and Retention Characteristics for Several Non-Uniform Soils in the Columbia Basin.

Gordon L. Stewart, PhD 1962 (Gardner). Water Content Measurement by Neutron Attenuation and Applications to Unsaturated Flow of Water in Soil.

Jack Jui-Chang Hsieh, PhD 1962 (Gardner). A Technique for Controlling Soil Water Content in the Vicinity of Root Hairs and Its Application to Soil-Water-Plant Studies.

Glendon W. Gee, PhD 1966 (Gardner). Water Movement in Soils as Influenced by Temperature Gradients.

Jan DeVries, PhD 1967 (Gardner). The Relative Effect of Energy Status and Transmissibility of Soil Water on Its Availability to Corn Plants.

Gaylon S. Campbell, PhD 1968 (Gardner). Soil Water Distribution Near Absorbing Root Hairs as Affected by Unsaturated Conductivity and Transpiration.

L. Fred Glenn, MS 1970 (Gardner). Soil Water Potential Control in the Root Hair Zone for Plant Growth Studies.

_____ PhD 1972 (Papendick for Gardner). The Limiting Resistance to Water Uptake by Plants: Soil Water Potential and Temperature Effects.

C. Calissendorff, MS 1970 (Gardner). An In Situ Leaf and Soil Water Psychrometer Having Low Temperature Sensitivity.

Melvin D. Campbell, PhD 1972 (Papendick for Gardner). The Lower Limit of Soil Water Potential for Potato Growth.

Gary Michael Ahlstrand, PhD in Botany, 1973 (with direction by Campbell). Microenvironment Modification to Favor Seed Germination in Disturbed Subalpine Habitats, Mount Rainier National Park, Washington.

Richard George Cline, PhD 1974 (Campbell). Seasonal, Diurnal, and Spatial Water Use and Water Relations of Selected Forest Species.

Ahmad Badri Mohammad, MS 1976 (Campbell). A field study of Water Relations and Growth Analysis of Two Winter Wheat Varieties.

M. L. Chakranopakhun Tongyai, MS 1976 (Campbell). An Evaluation of Finite Difference Numerical Methods for Soil-Plant Water Relations Studies.

_____ PhD 1977 (Campbell). Predicting Ponderosa Pine (Pinus Ponderosa Laws.) Seedling Survival from Environmental and Plant Parameters.

John E. Hammel, MS 1977 (Gardner). Influence of Root Distribution in the Thermal Region of Soil Heated by a Warm Water Pipe.

_____ PhD 1979 (Papendick). Modeling Tillage Effects of Subsoiling on Evaporation and Seedzone Water Content During Fallow in Eastern Washington.

Chi-Hua Huang, MS 1977 (Klock for Campbell). Some Changes in Energy Balance of a Forest Floor with Defoliation.

Esteban Rabie, MS 1977 (Campbell). Osmotic Adjustment in Leaves of Dryland Winter Wheat.

Alphonce James Shayo-Ngowi, MS 1977 (Campbell). Bound Water in Leaves of Dryland Wheat Varieties.

Craig Ross, PhD 1979, (Gardner). Tillage Pans and the Effects of Subsoiling on Potato Production in the Columbia Basin, Washington.

Stuart Whitely Childs, PhD 1980 (Campbell). Water Relations of Newly Planted Douglas-Fir Seedlings.

Susan Jean Riha, PhD 1980 (Campbell). Simulation of Water and Nitrogen Movement and Nitrogen Transformations in Forest Soils.

George Palmer Miller, MS 1981 (Campbell). Analysis of Radiant Environment in Forest Canopies: Technique and Application.

Kevin McInnes, MS 1981 (Campbell). Thermal Conductivities of Soils from Dryland Wheat Regions in Eastern Washington.

Caryn Elizabeth Bristow, MS 1983 (Campbell). Measurement and Simulation of Microbial Activity During Residue Decomposition: Freezing and Drying Effects.

Keith Leslie Bristow, PhD 1983 (Campbell). Simulation of Heat and Moisture Transfer Through a Surface Residue-Soil System.

Joel Green, MS 1983 (Campbell). Simulation of Denitrification in a Forest Soil.

Tim L. Jones, MS 1983 (Campbell). Spatial Variations of Density and Thickness in an Engineered Earthen Cover.

Jonathan Jay Halvorson, MS 1984 (Campbell). Vine Canopy Effects on Wall Surface Temperature and Energy Fluxes.

Harold L. Weaver, PhD 1984 (Campbell). A Mechanistic Model of Evapotranspiration from Saltcedar (Tamarix Chiniensis).

Babiker Abdalla Ibrahim, MS, 1985 (Miller). Effect of Subsoiling on Corn and Potatoes as Affected by Irrigation Frequency.

Little information is available on the educational philosophy of the department prior to World War II. However, S. C. Vandecaveye, soil microbiologist, who came to the University in 1924, Henry W. Smith, in soil morphology and genesis who came in 1940, and C. Dawson Moodie, soil chemist, who came in 1946, supported by a new Agronomy chairman, soil chemist B. R. Bertramson, constituted a scholarly base for expansion of soils programs in the post-war era.

The philosophy governing the development, which continues to the present, was that soil science must be built upon a solid foundation in the basic sciences. Advanced courses in physics, mathematics, chemistry, biology and geology became a standard part of student programs, particularly at the graduate level. Soils subject matter courses were kept at a minimum, resisting a practice followed in many agricultural areas of creating practical courses on "how to do" something. This philosophy was particularly true in soil physics, following the tradition of such early scientists as mathematician Charles S. Slichter (1864-1946), and physicists Edgar Buckingham (1867-1940), Lyman J. Briggs (1874-1963), Willard Gardner (1883-1964), L. A. Richards (1904-), E. C. Childs (1907-1973), Don

Kirkham (1908-), and others. Advanced students in soil physics were expected to become proficient in mathematics, physics, and physical chemistry particularly, and many of the theses produced reflect a strong background in basic sciences.

The department became noted for the strong physical science backgrounds of its graduates, a tradition which has continued. As science generally advances at an accelerated pace in this modern era the solid science base becomes particularly important. It is evident that new and important discoveries largely must depend upon the creativity and imagination of scientists educated to use all of the tools of science.