Research on Biomass Development and Residue Decomposition of Horticultural Crops for Erosion Prediction Models: Philosophy and Methodology of Data Collection

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Abstract

The increased demand for food and fiber, due to population increase, is causing marked acceleration of soil erosion. The Universal Soil Loss Equation (USLE) and its replacement, the Revised Universal Soil Loss Equation (RUSLE), are the most widely used of all soil erosion prediction models. Of the five factors in RUSLE, the cover and management (C) factor is the most important one from the standpoint of conservation planning because land use changes meant to reduce erosion are represented here. Even though the RUSLE is based on the USLE, this modern erosion prediction model is highly improved and updated. Alcorn State University entered into a cooperative agreement with the Natural Resources Conservation Service (NRCS) of the United States Department of Agriculture (USDA) in 1988 to conduct C factor research on vegetable and fruit crops. The main objective of this research is to collect plant growth and residue data that are used to populate databases needed to develop C factors in RUSLE, and used in databases for other erosion prediction and natural resource models. The enormous amount of data collected on leaf area index (LAI), canopy cover, lower and upper biomass, rate of residue decomposition, C:N ratio of samples of residues and destructive harvest and other growth parameters of canopy and rhizosphere made the project the largest data bank on horticultural crops.

INTRODUCTION

Even though research and education systems have transformed agriculture from a traditional to a high technology sector, soil erosion still remains as a major universal problem to agricultural productivity. Soil degradation is one of the greatest challenges facing mankind and its extent and impact on human welfare and the global environment are greater now than ever before (Lal and Stewart, 1990). Water erosion is the main degradation process, while human pressure, the reduction of plant cover, and the nature of the parent material are the main causes of soil erosion (Lopez Bermudez and Albaladejo, 1990). A review of the impacts of soil degradation found that 1.2 billion ha (almost 11% of the vegetative area in the world) have undergone moderate or worse degradation by human activity over the last 45 years (World Bank, 1992).

Alcorn State University, Mississippi, entered into a cooperative agreement with the Natural Resources Conservation Service (NRCS) of the USDA in 1988 to conduct a special study of plant and residue parameter values for fruit and vegetable crops. The main objective of this study is the part of a national conservation research effort designed

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to collect data on plant growth and residue data that are used to populate databases needed to develop C-factors in RUSLE, and used in databases for other erosion prediction and natural resource models.

USLE and C-factor

The Universal Soil Loss Equation (USLE) was developed at the National Runoff and Soil Loss Data Center in cooperation with Purdue University in 1954 and subsequently used around the world. It is reported that the USLE and its various modifications are considered to be the most suitable tool available for assessing sediment contribution to non point source pollution (Peterson and Swan, 1979). The USLE estimates long term average annual or long-term average seasonal erosion (Wischmeier and Smith, 1978). A general description of the USLE is given below.

$$A= R. K. LS. C. P$$

Where, A is the average annual soil loss. The factor R represents effects of climatic erosivity; K, soil erodibility; LS, slope length and steepness; C, cover and management; and P, supporting conservation practices. The cover and management (C factor) and topographic factors had the most significant effect on the overall model efficiency. This indicates that most of the research emphasis should continue to be placed on these parameters (Risse et al., 1993).

The C-Factor is the ratio of soil loss from land cropped under specific conditions to the corresponding loss from tilled, continuous fallow conditions (Wischmeier, 1972). The dimensionless C-factor, which has a range between 0 and 1, expresses the degree of protection of the soil surface by the crop or vegetation (Biesemans et al., 2000). LAI, canopy cover, plant height, and growth of upper and lower biomass are important factors considered in growth parameter studies of C-factor research.

RUSLE and C-factor

The USLE has been recently revised. A general description of RUSLE is given below (Renard et al., 1994).

A = R. K. LS. C. P, Where, A = predicted soil loss; R = climate erosivity; K = soil erodibility measured under standard unit plot conditions; LS = dimensionless factor representing the effect on erosion of slope length and steepness; C = dimensionless factor for cover and management; P = dimensionless factor for conservation support practices, such as contouring, strip cropping, terraces, deposition, etc. The RUSLE is a factor-based erosion model designed to predict long-term average soil losses carried by run-off from specific field slopes in specific cropping and management systems (Renard et al., 1997).

WEPP and C-factor

Water Erosion Prediction Project (WEPP) is a process based erosion model (Flanagan and Nearing, 1995). The objective of the Water Erosion Prediction Project is to develop a new generation water erosion prediction technology for use by the USDA-Natural Resources Conservation Service, USDA-Forest Service, United States Department of Interior (USDI) -Bureau of Land Management, and other organizations involved in soil and water conservation and environmental planning and assessment (Foster and Lane, 1987). The plant growth components for cropland calculates above and below ground biomass production for both annual and perennial crops in cropland situations, and for rangeland plant communities in rangeland situations (NSERL, 1995).

WEPS and C-factor

The Wind Erosion Prediction System (WEPS), developed by the USDA-ARS scientists, is process based, continuous daily time-step model that stimulates weather, field, conditions, and erosion (Hagen et al., 1995). A crop growth model CROP is one of the submodels in the WEPS. The model calculates daily production of masses of roots, leaves, stems, and reproductive organs of leaf and stem areas. At harvest, an estimate of the amount of dead biomass remaining on the soil surface is required for the DECOMPOSITION and other submodels of WEPS (Retta and Armbrust, 1995).

Residue Decomposition and C:N Ratios

Crop residue management has been established as a valuable technology for reducing erosion and improving run-off water quality from agricultural lands (Mustaghimi et al., 1988). Residue management has become an important component of conservation tillage systems because surface residues help reduce water loss and erosion (Schomberg and Steiner, 1994). The crop residue decomposition component of WEPP is based on the RESMAN Residue Management Model (Stott, 1991). The Natural Resources Conservation Service estimates that 617 Kg ha^{-1} of residue is necessary to protect soil surfaces from the erosive effects of rainfall and water run-off (Kusmenoglu and Muehlbauer, 1998).

Surface Residue and Horticultural Crops

The benefits of surface residues or mulch in conserving soil moisture in horticultural crops has been known for many years (Emerson, 1903). Growing winter cover crops for surface residues in conservation tillage provides mulch that may decrease soil temperature and influence vegetable yields, depending on cover residue selection (Coolman and Hoyt, 1993). Legume residues have increased vegetable yields when compared to grass residues (Hoyt and Hargrove, 1986).

Conservation Tillage and Horticultural Crops

Conservation tillage (CT) has become an accepted cultural practice for many seeded agronomic crops since its introduction in the 1950s. Horticultural crops have not been studied as thoroughly as agronomic crops in CT experiments (Hoyt et al., 1994). Direct seeded vegetables such as sweet corn and squash can be planted easily by current no-till seeders designed for agronomic row crops (Hoyt, 1999). CT improved or maintained yields similar to conventional tillage in tomatoes (Morse et al., 1982), field beans and peppers (Lugo - Mercando et al., 1984), potatoes (Mundy et al., 1999), cabbage and broccoli (Hoyt et al., 1996), and lima beans (Beste, 1973).

MATERIALS AND METHODS

Parameter Measurements and their Techniques

The data collection procedures for the C factors is comprehensive and requires a series of very technical procedures. The procedures were established by USDA-NRCS and ARS Scientists in cooperation with the scientists of Alcorn State University's Conservation Research Team in 1989 and refined and updated several times to make it highly acceptable to RUSLE and WEPP.

Two experimental plots are simultaneously raised and maintained for the same crop; one for the destructive harvest studies and the other for yield, leaf area index (LAI), percent canopy cover, date of leaf drying initiation (senescence), and percent residue cover after harvesting and disking. Destructive harvest study is carried out for every 15 days from the date of emergence until the final harvest. The parameters measured: a) LAI, b) canopy cover percent, c) canopy height, d) stem diameter, e) root depth, f) root mass (fresh & dry), g) upper biomass (fresh and dry), h) edible portions, i) root/shoot ratio, and j) rhizosphere width.

Supposing plant to plant distance = 30.48 cm and row to row distance = 91.44 cm, then one plant area = 30.48 x 91.44 = 2787.0912 sq cm. 2787.0912 sq cm contains 1 plant.

Hence, 1 meter square may contain $\frac{1 \times 100 \times 100}{2787.0912}$ plants = 3.5879701 plants

Supposing the dry weight of one plant's specific portion = (x) grams, then 3.5879701 will weigh 3.5879701(x) gms = $\frac{3.587970\,(x)}{1000}$ Kg = .0035879701 (x) Kg.

Hence, the factor = .0035879701. This factor when multiplied by the actual value obtained for one plant's average dry weight of its specific portion (root, shoot or edible portion) will give the needed value in Kg m^2.

Zenith Angle

Zenith angle is the angle the sun makes with respect to a line vertical to the earth's surface. Zenith angle of the sun is required for inversion of canopy light transmission data to determine leaf area index. The zenith angle is determined with a device called board/scale zenith angle device before the ceptometer reading is taken.

Leaf Area Index (LAI) and Percent Canopy Cover

The ideal time to record the ceptometer reading is between 10:00 a.m. and 2:00 p.m.

Residue Measurement Technique

Various residue measurement techniques are currently in use. A line transect method covering both line-intercept and point intercept is used to measure the residue cover. A cord with equally spaced knot markers is stretched diagonally across the plot and coincidences of the markers and pieces of crop residue on the soil surface are visually counted (Morrison et al., 1993).

Non-edible Plant Material Decay Study

Fresh plant residues collected from the field immediately after final harvest are cut into small pieces. Cuttings are weighed immediately and packed in previously washed, dried and weighed fiberglass bags. Roots and shoots are surfaced and sub-surfaced at 15.24 cm deep for a period of six month study. The dried residue is ground and analyzed for C, H, and N.

Weather Information and Data Management

Weather information are recorded by a computerized weather station and assembled as a data base according to RUSLE and WEPP model specifications. Data gathered in the field and laboratory are compiled and stored using a data base management program called SEIMS (Soil Erosion Information Management System).

PROGRESS AND ACHIEVEMENTS

The enormous data collected on leaf area index (LAI), canopy cover, lower and upper biomass, rate of residue decomposition, C:N ratio of samples of residues and destructive harvest, and other growth parameters of canopy and rhizosphere made the project the largest data bank on horticultural crops. The project has completed data collection on 32 crops raised on 249 research plots with a total of 91,024 readings until summer 2001.

Horticultural Crops Studied

Bell pepper, broccoli, cabbage, cantaloupe, cauliflower, Chinese cabbage, collards, cowpea, English peas, hot pepper, Irish potato, kale, lettuce, mustard, nectarine, okra, onion, peanut, plum, radish, snap beans, spinach, squash, strawberry, sweet corn, sweet potato, tomato, turnip and watermelon.

Agronomic Crops Studied

Cotton, soybean and canola.

Destructive Harvest Studies

Completed data collection on 32 crops.

Non-edible Plant Material Decay Study

3114 samples from 21 crops for rate of decomposition.

CHN Analysis

(a) Samples from destructive harvest – 557
(b) Samples from residue decomposition – 3114

Study Continues On

Conventional and no-till vegetable production. Organic and inorganic muscadine, blueberry, peach, plum and nectarine production.

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