

**C-FACTOR RESEARCH ON HORTICULTURAL CROPS FOR EROSION PREDICTION MODELS:  
PHILOSOPHY AND METHODOLOGY OF DATA COLLECTION**

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## ABSTRACT

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. 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 NRCS of 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.

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## INTRODUCTION

The increased demand for food, fiber and firewood, due to population increase, is causing marked acceleration of soil erosion. The quality and degradation of soils are more serious problems in the developing countries than in the USA, and a number of these countries are already using most of their potentially arable soils (Duval, 1982). Buringh (1982) estimates that 4 million ha (10 million acres) of the world's productive land are lost each year through soil degradation and that worldwide annual conversion of farmland to non- agricultural uses is 8 million hectares (20 million acres). 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).

The principal soil and water conservation programs of USDA were established in the 1930s, amid the stark atmosphere of the Great Depression and the Dust Bowl. The National Resources Inventory (NRI) was conducted by the Soil Conservation Service (SCS) in 1977 and again in 1982. A thorough evaluation of all USDA conservation programs was required by the Soil and Water Resources Conservation Act (RCA) of 1979 (Public Law 95-192). Federal conservation programs over the past 45 years have cost \$21.3 billion, adjusted for inflation. Farmers, states and local groups have contributed \$21.6 billion, also adjusted for inflation.

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Yet, after a commitment of \$43 billion, the problem remains, and the need for additional effort grows each year (Bentley, 1985).

Soil erosion is a major conservation issue on about 50% of U.S. cropland (Larson, 1981). Previous studies by Crosson (1985), Benbrook et al. (1984), and Myers (1985) had estimated the on-farm costs of soil erosion in the U.S. at between \$525 million and \$1 billion per year. In the U.S., up to one billion tons of agricultural soils are deposited in waterways every year, and an estimated one-half of the suspended sediments in U.S. surface water originate from agriculture (OECD, 1994).

## USLE & 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. The development of USLE and its introduction to agriculture created a new era of modeling of physical phenomenon. It is reported that the USLE and its various modifications are considered to be the most suitable tool available for assessing sediment contribution to nonpoint source pollution (Peterson and Swan, 1979).

The USLE grew from the analysis of data collected over thousands of plot-years from the 1940s to the 1970s. 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.

$$A = R K L S C P$$

Where A is the average annual soil loss. The factor R represents effects of climatic erosivity; K, soil erodibility; LS, slope length and steepness; and 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).

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The C-Factor is the ratio of soil loss from land cropped under specific conditions to the corresponding loss from tilled, continuous fallow conditions. The correspondence of periods of highly erosive rainfall with periods of poor or good plant cover differs appreciably between climatic areas; therefore, the value of C for a particular cropping and management system will not be the same for all parts of the country. Locational C values are derived using specific rainstorm-trimming probabilities and research data that reflects the erosion-reducing effectiveness of crops and management during successive periods within a rotation cycle (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).

Complete cover at the soil surface fully protects the soil from raindrop impact, and management that changes aggregate stability effects interrill erosion. These C-Factor effects are divided into three classes: (i) canopy effects, (ii) ground-cover effects, and (iii) within-soil effects (Wischmeier, 1975).

Kind of tillage, time of tillage, implements used, postemergence cultivation, crop planted, time of planting, crop sequence, residue cover of soil surface, and changes in soil organic matter affect the C-factor. Leaf area index (LAI), canopy cover, plant height, and growth of upper and lower biomass are important factors considered in growth parameter studies of C-factor research. Leaf area index is one of the most important observations in C-factor research. LAI is a fundamental attribute of plant canopies because the leaves are the dominant photosynthetically active tissue in the canopies (Pearson, 1984). Leaves dominate the interaction of electromagnetic radiation with plants so that

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interpretation of remote spectral observations is based primarily on foliage characteristics (Wiegand et al., 1972). In the photo-synthetically active radiation (PAR) wavelengths, chlorophyll and other pigments determine the optical behavior of leaves (Knippling, 1970).

Measurement of Leaf Area Index (LAI) or leaf area per unit ground area, is useful for studying crop growth, radiation interception, and water use (Dewitt, 1965; Ross, 1981). Photosynthesis is closely related to dry matter production in most crops, and dry matter production determines yield (Moss and Musgrove, 1971; Yoshida, 1981). Canopy photosynthesis measurements integrate the effects of leaf area, leaf angle, plant density, and shading effects of leaves, stems, or panicles (Evans, 1993; Fischer, 1993; Ishii, 1993). Crop growth can be considered as the product

of incoming solar radiation, the fraction of that intercepted by the crop as determined by the leaf area index (LAI), and the efficiency with which the intercepted radiation is used to produce biomass, i.e., radiation use efficiency, RUE (Nam et al., 1998). The dry matter productivity of many crops has been closely linked with light interception (LI), and RUE is generally considered constant for a given crop species (Muchow and Sinclair, 1994).

The distribution of leaf and stem area with height is needed to determine the reduction of air flow through the plant canopy and, thus, the velocity near the soil surface (Bache, 1986). The energy of a falling raindrop available at the soil surface for detachment of soil particles depends on the canopy cover (Wischmeier and Smith, 1978; Quinn and Lafflen, 1983). The plant canopy increases the drop size; alters the spacial distribution (Armstrong and Mitchell, 1987), and decreases the volume of rain reaching the soil surface once 50% cover is produced (Morgan, 1985). One common output of all plant growth simulation models is the dry weight of biomass produced. Although dry weight is often required in soil erosion modeling, the new Wind Erosion Research Model (WERM),

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now called Wind Erosion Prediction System (WEPS), (Hagen, 1991) and Water Erosion Prediction Project (WEPP) (Lane and Nearing, 1989) also require information on the structure of the plant canopy.

### **RUSLE & C-FACTOR**

The USLE has been recently revised. The U.S. Department of Agriculture (USDA), Soil Conservation Service (SCS) made the decision to implement RUSLE as its official erosion prediction and conservation planning tool (Soil Conservation Service, 1993). A general description of RUSLE is given below (Renard et al., 1994).

$A = R \cdot K \cdot LS \cdot C \cdot P$  Where

A = predicted soil loss (tons acre<sup>-1</sup> year<sup>-1</sup>)

R = climate erosivity ([hundreds of ft- tons] inch acre<sup>-1</sup> hr<sup>-1</sup> year<sup>-1</sup>)

K = soil erodibility measured under standard unit plot conditions (tons hour [hundreds of ft-tons]<sup>-1</sup> in<sup>-1</sup>)

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 Revised Universal Soil Loss Equation (RUSLE) uses the same fundamental structure as did the USLE, but it represents a significant improvement over USLE technology in calculation of each of the factors (Renard, 1992;

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Renard et al., 1991). The RUSLE has integrated several changes since it was first released by Soil and Water Conservation Society (SWCS) in December, 1992. The changes include seasonal variation in soil erodibility (K), new methods of calculating cover-management factors (C), new conservation-practice values (P), and rainfall-run-off erosivity (R) for rangeland, and computerization of the algorithms. RUSLE is also capable of accounting for rock fragments in and on the soil (Renard et al., 1991).

The RUSLE has the following differences compared with the USLE on C-factor. RUSLE uses subfactors such as prior land use, canopy cover, surface cover, surface roughness, and soil moisture. The C-factor is more refined by dividing each year in the rotation into 15 day intervals, calculating the soil loss ratio for each period. It recalculates a new soil loss ratio every time a tillage operation changes one of the subfactors. RUSLE provides improved estimates of soil loss changes as they occur throughout the year, especially relating to surface and near-surface residue and the effects of climate on residue decomposition (Renard et al., 1994). The USLE and its replacement, the RUSLE, are the most widely used of all soil erosion prediction models. Of the five factors of RUSLE, the C-factor is the most important one from the standpoint of conservation planning because land use changes meant to reduce erosion are represented here.

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). The RUSLE can assess both on-site soil losses and off-site sediment accumulations. It requires only a limited amount of data to perform a field-scale erosion analysis for large areas, compared to other process based models (Bieseman et al., 2000).

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## **WEPP & 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, USDI-Bureau of Land Management, and other organizations involved in soil and water conservation and environmental planning and assessment (Foster and Lane, 1987).

The Water Erosion Prediction Project (WEPP) is a computer model to predict water-induced soil erosion, storm run-off, root zone soil water, evapotranspiration, plant growth, and snow melt on cropland, rangeland, and forest land watersheds (USDA, 1989). The WEPP model represents a new erosion prediction technology based on the fundamentals of infiltration theory, percolation, soil physics, plant science, hydraulics, and erosion mechanics. In theory, WEPP provides several major advantages over existing hydrologic models; normally, it reflects the effects of land-use changes due to agricultural, range, and forestry practices, and it models spacial and temporal variability of the factors affecting the surface and subsurface water quality and quantity along a single hillslope or over a small watershed. The WEPP model can be divided into six conceptual components: climate generation, hydrology, plant growth, soils, management, and erosion (Savabi et al., 1995).

The WEPP model may be used in both hillslope and watershed applications. The major inputs to WEPP are a climate data file, a slope data file, a soil data file, and a cropping/management data file (NSERL, 1995). The cropping/management input file contains the largest number of different types of input parameters which describe the different plants, tillage implements, tillage sequences,

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management practices, etc. 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). The plant growth routines in WEPP are based upon an Epic. (William et al., 1989) model approach which predicts potential growth based upon daily heat unit documentation. Actual plant growth is then decreased if water or temperature stress exist. In terms of erosion, perhaps the most important factor related to plant growth is the amount of biomass produced by the crop. (NSERL, 1995). Because of its complexity and the large number of input parameters in the WEPP plant growth model, only a few of those input parameters were collected in this study.

## **WEPS & C-FACTOR**

The Wind Erosion Prediction System (WEPS), developed by the USDA-ARS scientists, is process based, continuous daily time-step model that simulates weather, field, conditions, and erosion (Hagen et al., 1995). It is intended to replace the predominately empirical Wind Erosion Equation (WEQ) (Woodruff and Siddoway, 1965) as an erosion prediction tool. The USDA-ARS scientists have also developed another process based but more empirical model that is known as the Revised Wind Erosion Equation (RWEQ) (Fryrear et al., 1998).

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 and 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). Standing residue is more effective than flat residue, because it absorbs more of the wind's energy

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(Siddoway et al., 1965). Like the plant growth model in WEPP, the WEPS plant growth model is very data intensive. Only a few of the input parameters were collected in this study.

## **RESIDUE DECOMPOSITION & 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). Surface residue management is the most promising and practical erosion control practice in use today. Crop residues influence soil quality, nutrient cycling, and microbial processes and contribute significant amounts of N to the main crop (Vigil et al., 1991).

Residue management has become an important component of conservation tillage systems because surface residues help reduce water loss and erosion (Schomberg and Steiner, 1999). Surface residues decompose slower than incorporated residues (Douglas et al., 1980; Schomberg et al., 1994). The rate of crop residue decomposition is important from both agricultural and environmental standpoints. Decomposition of crop residues is a function of organic N content or C/N ratio (Gilmor et al., 1998). Decomposition rates have been shown to differ for the same residue in different soils (Ajwa and Tabataba, 1994).

Litter from leaves, stems, branches, coarse roots, and fine roots is allocated into a readily decomposable (metabolic) root or a resistant (structural) residue pool based upon its lignin: N ratio (Pastor and Post, 1986). Soil litter carbon is divided into two major organic pools: residue (Woody debris, leaf litter and roots) and humus (Soil organic matter). Each of the carbon pools has an associated mineralization rate, efficiency of carbon transformation, and a specific range of C:N and C:P ratios (Lowrance et al., 2000).

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Plant residue decomposition for croplands is based upon a "decomposition day" approach, which is similar to the growing degree day approach used in many plant growth models. Each residue type has an optimal rate for decomposition, and environmental factors of temperature and moisture act to reduce the rate from its optimum value. The WEPP model tracks the type and amounts of residue from the previous 3 crop harvests. The model also allows several types of residue management, including residue removal, shredding, burning, and contact herbicide application (NSERL, 1995).

The crop residue decomposition component of WEPP is based on the RESMAN Residue Management Model (Stott and Rogers, 1990; Stott and Barrett, 1993; Stott, 1991). This component estimates the amount of residue present daily as standing, flat or buried, as well as dead roots. It also determines the amount of surface cover provided by the residue.

Microbial biomass may reduce losses of N and other nutrients during periods of low crop demand, and may act as a source of nutrients during active crop growth (Breimer and Kessel, 1992). Microbial biomass is generally highest in the fall and spring. Greater microbialization of nutrients in the microbial biomass during this period may conserve nutrients until the following crop is actively growing. The decline in microbial biomass during the summer may increase the nutrient supply for plants (Bremer and Kessel, 1992). Freeze- thaw cycles during the overwinter period may also enhance C availability (Inversan and Snowden, 1970).

Legumes have been long known to benefit sub- sequence crops. Although limited plant availability of legume N is primarily due to stabilization of N in organic forms, losses of legume N through  $\text{NH}_3$  volatilization, denitrification, or leaching may also be considerable (Bremmer and Kessel, 1992). Ladd and Amato (1986) and

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Janzen et al. (1990) reported that losses of legume  $^{15}\text{N}$  were as great or greater than uptake by a subsequent crop. Mineralization of N is generally rapid from plant residues with a low C:N ratio (Amato et al., 1987; Fox et al., 1990) because N is in excess of the requirements for microbial growth. Nitrogen in plant residue with a high C/N ratio is retained by the microbial biomass (Ocio et al., 1991) and only slowly released.

The potential for considerable losses of  $\text{NH}_3\text{-N}$  from immature plant residues decomposing on the soil surface was observed by Whitehead et al. (1988) and Janzen and McGinn (1991). Losses of  $\text{NH}_3\text{-N}$ , however, were negligible when plant residues were buried (Janzen and McGinn, 1991). The influence of plant residues on plant-available N also depends on the effects of plant residues on net mineralization of other sources of N in the soil (Bremer and Kessel, 1992). Yacob and Blair (1980) and Fox et al. (1990) also reported that additions of legume residues increased indigenous soil N mineralization by 14 to 39% of the amount of N added. Wilson and Hargrove (1986), using crimson clover (*Trifolium incarnatum* L.) residues contained in nylon mesh bags, noted that N disappearance was faster for buried residues than with surface placement.

Residue inputs subsequently modify soil properties important to soil quality and crop production (Carter and Rennie, 1984; Collins et al., 1992). Crop residue, if retained on the soil surface, can dramatically reduce soil erosion. Crop residue requirements for erosion control depend on the type of residue and severity of erosion (Unger, 1988). However, it is estimated that 2200 Kg  $\text{ha}^{-1}$  of crop residue reduces soil loss from water erosion by 65% (Wischmeier, 1973). The Natural Resources Conservation Service estimates that 617 Kg  $\text{ha}^{-1}$  of residue is necessary to protect soil surfaces from the erosive effects of rainfall and water run-off (Kusmenoglu and Muehlbauer, 1998).

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## **SURFACE RESIDUE & HORTICULTURAL CROPS**

The benefits of surface residues or mulch in conserving soil moisture in horticultural crops has been known for many years (Emerson, 1903) with materials such as black plastic emulating the benefits of crop residues (Estes et al., 1985). 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) and have increased nitrogen, potassium, and phosphorus recycling within the soil horizon (Wagger, 1993).

## **CONSERVATION TILLAGE & RESIDUE MANAGEMENT**

Under conventional tillage practices, plowing results in mixing of the soil profile and the burial of crop residues. With no-tillage management the soil is not plowed and crop residues accumulate on the soil surface as a mulch. These differences in soil disturbance and residue placement and their effects on soil physical and chemical properties (Phillips and Phillips, 1984) can influence the composition, distribution and activity of soil microbial communities (Doran, 1980; Lynch and Panting, 1980; Rice and Smith, 1982; Groffman, 1985). Knowledge of these influences can be important to understanding nutrient cycling (Hendrix et al., 1986; Andren et al., 1990; Beare et al.,

1992) and organic matter dynamics (Doran, 1980; Holland and Coleman, 1987) in different tillage and residue management systems.

In conventional tillage and no-tillage soils the "native" placements of residues (i.e., buried in CT, surficial in NT) significantly alters residue - associated microenvironments (Van Doren and Ahmaras, 1978). Water content, temperature, and nutrient proximity are among the most important variables that differ with residue placement (Beare et al., 1992).

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In grain sorghum, buried residues (CT) had higher densities of fungal hyphae but fewer fungal colony-forming units than surface residues (NT). Buried decay rates were 3.4 times faster than surface residues. Fungal hyphae were more abundant in NT than CT mineral soils but there were no differences in fungal colony-forming units (Beare et al., 1993).

No-tillage to control soil erosion and enhance rainfall capture and retention is a proven practice in the Southeastern USA, particularly on the broadly sloping lands of the Piedmont and Appalachian Plateau. Yield increases due to no-tillage have been most notable for corn and double-crop soybean, and were primarily attributed to greater soil water availability from increased infiltration (Jones et al., 1969; Moscher et al., 1972; Waggoner and Denton, 1989). In contrast, however, there are reports of grain yields being equal or lower with no-tillage than with conventional tillage systems. On heavy clay soils in the Mississippi Blacklands Prairie region, no-tillage resulted in a 20% soybean yield reduction compared with conventional tillage (Hairston et al., 1984).

## **CONSERVATION TILLAGE & 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). The introduction of no-till transplanter has provided a means for planting bare rooted or containerized transplants in undisturbed soil (Morrison et al., 1973). 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).

In Kentucky, Knavel et al., (1985) obtained greater sweet corn and popcorn yields with conventional tillage. CT improved or maintained yields similar to conventional tillage

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in tomatoes (Morse et al., 1982), field beans and peppers (Lugo - Mercado et al., 1984), potatoes (Mundy et al., 1999), cabbage and broccoli (Hoyt et al., 1996), and lima beans (Beste, 1973).

## **OBJECTIVE**

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 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.

## **MATERIALS & METHODS**

### **Parameter Measurements and their Techniques**

The data collection procedures for the C-Factor 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. Alcorn State University is located at the Southwestern part of Mississippi and the C-Factor Research Project is located on Memphis Silt Loam Soil (Typic Hapludalf, Silty, Mixed, Thermic) coming under the order Alfisols. Alfisols have a clay and nutrient enriched subsoil. They commonly have a mixed vegetative cover and are productive for most crops.

Two experimental plots are simultaneously raised and maintained for the same crop; one for the destructive harvest

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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. Plants are randomly selected for destructive harvest studies.

Destructive harvest study is carried out for every 15 days from the date of emergence until the final harvest. The parameters which are measured at each destructive harvest are:

- a) Leaf area index (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
- j) Rhizosphere width

Root, shoot, and edible portions are always separated and their weights are recorded after drying to get the value of dry weights in Kg m<sup>2</sup> as follows.

Supposing plant to plant distance = 12"

Row to row distance = 36"

Then one plant area = 12 x 2.54 x 36 x 2.54 sq cm

= 2787.0912 sq cm

2787.0912 sq cm contains 1 plant

Hence, 1 meter square may contain

$$\frac{1 \times 100 \times 100 \text{ plants}}{2787.0912} = 3.5879701 \text{ plants}$$

Supposing the dry weight of one plant's specific portion = (x) grams

Then 3.5879701 will weigh — 3.5879701(x) gms

$$= \frac{3.587970(x) \text{ Kg}}{1000} = .0035879701(x) \text{ Kg}$$

Hence, the factor = .0035879701

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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  $\text{Kg m}^2$ .

#### **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 (AccuPAR Operators' Manual).



Fig. 1. Zenith angle is determined with the board/scale zenith angle device.

The zenith angle is determined with a device called board/scale zenith angle device before the ceptometer reading is taken (Fig. 1).

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## LEAF AREA INDEX (LAI):

LAI is the area of leaves per unit area of soil surface. LAI and percent canopy cover are measured with the AccuPAR (Fig. 2 & 3). AccuPAR is a battery-operated linear PAR ceptometer used for the collection of light interception data in crop and forest canopy research. AccuPAR's sensors



Fig. 2. Leaf Area Index (LAI) and percent canopy cover are measured with the AccuPAR. Here, photosynthetically Active Radiation (PAR) is measured above the canopy.

measure PAR (Photosynthetically Active Radiation) in the 400 to 700 nanometer wavelength. Biomass production in plant communities is directly related to PAR interception (AccuPAR Operators Manual).

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Fig. 3. AccuPAR measures light interception data below the canopy for LAI and percent canopy cover.

Ceptometer reading is taken between 10:00 a.m. and 2:00 p.m. The ceptometer is first set in READ mode F2, then use F4 for segmented probe par sampling with no external point sensor. The user will then center the bubble in the circle and take one reading unshaded F1 and one reading shaded F4. By pressing the F4 key, the probe will automatically calculate 12 readings and average them. This will give the Fd value.

The next step is to take the readings inside the plot. To minimize the chances of errors, the border rows of the undisturbed yield harvest area will be avoided. By the same procedure mentioned above, the user should take 1 reading above the canopy with a F1 key. Next, by pressing the F4 key 1 time, the ceptometer will automatically calculate and average 12 readings below the canopy. The center of the probe should be placed at the stem of the plant and moved slowly away as the ceptometer calculates the readings.

**CALCULATION OF LAI:**

Take one PAR measurement above the canopy, one below the canopy and record the average.

$$i = \text{PAR below/PAR above}$$

In READ mode, take 1 reading shaded F1 with the tip of the ceptometer shaded by a 10 cm diameter shade at a distance of about 1 meter, and 1 reading unshaded. Record the average.

$$F_d = \text{PAR shaded/PAR unshaded}$$

$$F_b = 1 - F_d$$

Calculate the zenith angle:

$$= \arctan (X/10).$$

Where X is the shadow length (cm) and 10 is the height (cm) of vertical piece.

$$K = 1/\cos$$

Calculate LAI:

$$A = 1 - 1/2 K$$

$$B = F_b - 1$$

$$C = A * B$$

$$D = C * \ln i$$

$$E = 0.86 (1 - 0.47 F_b)$$

$$\text{LAI} = D/E$$

**PERCENT CANOPY COVER:**

This measurement is taken using function 2 of the ceptometer. The border rows are avoided to record this reading. Place the instrument above the leaf canopy in full sunlight and press the A button. This  $D_v$  value is the measurement when the ceptometer probe is fully exposed to sunlight. Press B button twice to clear this display. After taking 10 readings below the canopy press the B button to display the arithmetic mean  $N_{um}$ . Percent canopy cover (PCC) =  $(1 - N_{um}/D_v) * 100$ .

**RESIDUE MEASUREMENT TECHNIQUE**

Crop residues were originally quantified in terms of dry weight per unit area until conservationists learned that percentage of soil covered by residues correlated better with erosion control than dry weight (Gilley et al., 1986).

Additional emphasis on quantifying percentage cover has been generated by the Food Security Act of 1985 and Food, Agriculture, Conservation and Trade Act of 1990 (USDA. 1985; USDA. 1990).

Percentage residue cover is used to characterize the soil surface coverage by pieces or fragments of plant material as seen by a nadir view and herein termed "cover", given in units of "% - cover" (Morrison et al., 1997). 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 used for this study. They are cut

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into small pieces, almost to the same size and type of cuttings usually produced by the rotary tiller. Cuttings are weighed immediately and packed in previously washed, dried and weighed fiberglass bags. Each non-edible part in triplicate is checked for its initial moisture and dry matter content. Labeled bags are spread over the well-plowed field. Each bag is tied with a thread across the field to prevent any movement that could happen by heavy winds or animal pests. Seventy two bags of roots and 72 bags of shoots are used for each crop. Roots and shoots of 36 bags each are surfaced and the same number of bags are sub-surfaced at 6" deep for a period of six month study. Two bags of shoots and 2 bags of roots are collected from the field every ten days (Fig. 4). Bags are very carefully brushed to remove the adhering soil particles.



Fig. 4. Residue decomposition study using fiberglass bags. Surfaced and subsurfaced roots and shoots are studied for a period of six months.

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Residue is dried, ground and analyzed for C, H, and N analysis with the Elemental Analyzer E.A. 1108 (Fig. 5). The principle of analytical method is based on the complete and instantaneous oxidation of the sample by "flash combustion" which converts all organic and inorganic substances into combustion products. The resulting combustion gases pass through a reduction furnace and are swept into the chromatographic column by the carrier gas (helium) where they are separated and detected by a thermal conductivity detector (TCD) which gives an output signal proportional to the concentration of the individual components of the mixture (Carlo Erba Instruments Production Manual).



Fig. 5. C, H, and N analysis using the Elemental Analyzer E. A. 1108. The principle of analysis is the oxidation of the sample by "flash combustion".

### **MINIMAL-TILLAGE AND NO-TILL STUDIES**

Considering the highly erodible nature of the Memphis Silt Loam, a minimal-till study was initiated in 1992.

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The objective of this study was to determine the effect of minimum tillage on the yield of sweet corn, cowpea, and snap beans with the yearly treatments of wheat, clover, vetch and control.

Two no-till plot have been established in spring 2000 to raise vegetable crops. Two crops will be raised simultaneously on conventional-till and no-till plots to compare for yield, LAI, percent canopy cover, canopy height and upper biomass.

### **WEATHER DATA:**

Weather information are recorded by a computerized weather station and assembled as a data base according to RUSLE and WEPP model specifications.

### **DATA MANAGEMENT:**

Data gathered in the field and laboratory are compiled and stored using a data base management program called SEIMS (Soil Erosion Information Management System). It has been updated with more recent software; i.e; from DOS to Windows base program for recording data and generating reports. Units used for the parameter values correspond to those agreed upon by the Alcorn State University's C-Factor Project Team, USDA-ARS, and NRCS. Both field and climatic data collected in the project are transmitted to the user agencies at regular scheduled intervals.

### **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.

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**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, canola,

**Study continues on:** (1) Vegetables on conventional & no-till, and (2) muscadine, blueberry, peach, plum, and nectarine.

**Destructive Harvest Studies:** Completed data collection on 32 crops raised on 246 research plots with a total of 87,984 readings until Fall 2000.

**Non-Edible Plant Material Decay Study:**

3114 samples from 21 crops

**No-till:** Studies on vegetables continue

**CHN Analysis:**

(a) Samples from destructive harvest - 557

(b) Samples from residue decomposition - 3114

**Number of Publications:**

(a) Papers presented and published at regional, national and international conferences - 21

(b) Theses - 3

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## REFERENCES

- AccuPAR Operators' Manual. Decagon, 950 NE Nelson Court, Post Office Box 835, Pullman, Washington 99163.
- Andren, O. T., Lindberg, U. Bostrom, M. Clarholm, A-C. Hansson, G. Johansson, and J. Lagerlof. 1990. Organic carbon and nitrogen flows. In O. Andren et al. (ed.) Ecology of arable land: Organisms, carbon and nitrogen cycling. Ecology Bull. 40:85-126.
- Ajwa, H. A., and M.A. Tabatabai. 1994. Decomposition of different organic materials in soils. Bull. Fertile Soils 18: 175-182.
- Amato, M., J.N. Ladd, A. Ellington, G. Ford, J.E. Mahoney, A.C. Taylor, and D. Walscott 1987. Decomposition of plant material in Australian soils. IV. Decomposition *in situ* of <sup>14</sup>C- and <sup>15</sup>N- labeled legume and wheat materials in a range of southern Australian soils. Aust. J. Soil Res. 25:95-105.
- Armstrong, C. L., and J. K. Mitchell. 1987. Transformation of rainfall by plant canopy. Trans. ASAE 30:688-696.
- Bache, D.H. 1986. Momentum transfer to plant canopies; influence of structure and variable drag. Atmos. Environment 20:1369-1378.

26

- Beare, M. H., R. W. Parmelee, P. F. Hendrix, W. Cheng, D. C. Coleman, and D.A. Jr. Crossley. 1992. Microbial and faunal interactions and effects on litter nitrogen and decomposition in agricultural ecosystems. Ecological Monographs.62:569-591.
- Beare, M. H., B. R. Pohlad, D. H. Wright, and D. C. Coleman. 1993. Residue Placement and Fungicide Effects on Fungal Communities in Conventional and no-tillage Soils. Soil Sci. Soc. Am. J. 57:392-399.
- Benbrook, C., P. Crosson, and C. Ogg. 1984. Resource Dimensions of Agricultural Policy, in Proc. Agricultural and Food Policy Conference. Berkeley, CA: Giannini Foundation.
- Bentley, O. G. 1985. Soil erosion and crop productivity: A call for action. p.1-7. In R.F. Follet and B. A. Stewart (ed.). Soil erosion and crop productivity.
- Beste, C. E. 1973. Evaluation of herbicides in no-till planted cucumber, tomatoes, and lima beans. N. E. Proc. Weed Sci. Soc. 7:232-239
- Biesemans, J. M., Van Meivenne, and D. Gabriels. 2000. Extending the RUSLE with the Monte Carlo error propagation technique to predict long-term average off-site sediment accumulation. J. Soil and Water Conservation. 55(1):35-42.
- Bremer, E., and C. van Kessel. 1992. Soil microbial biomass dynamics after addition of lentil and wheat residues. Soil Science Am. J. 56:1141-1146.
- Bremer, E., and C. van Kessel. 1992. Plant-Available Nitrogen from Lentil and Wheat Residues during a subsequent Growing Season. Soil Sci. Am. J. 56:1155-1160.

27

- Buringh, P. 1982. Potentials of world soils for agricultural production. p. 33-42. In managing soil resources. Plenary papers of the 12<sup>th</sup> Int. Cong. of Soil Science, New Delhi, India. Int. Soc. Soil Sci., Wageningen, The Netherlands.
- Carlo Erba Instruments Production Manual. Carlo Erba Instruments, P. O. Box 10364. 120110 Milan, Cable Erbadas, Milan.
- Carter, M. R., and D. A. Rennie. 1984. Dynamics of Soil microbial biomass N under zero and shallow tillage for spring wheat, using <sup>15</sup>N area. Plant

Soil 76:157-164.

- Collins, H. P., P. E. Rasmussen, and C. L. Douglas. 1992. Crop rotation and residue management effects on soil carbon and microbial dynamics. *Soil Sci. Soc. Am. J.* 56:783-788.
- Coolman, R. M. and G. D. Hoyt. 1993. The effects of reduced tillage on the soil environment. *HortTechnology* 3(2):143-145.
- Crosson, Pierre. 1985. "National Costs of Erosion Effects on Productivity," in *Erosion and Soil Productivity*. St. Joseph, MI: American Society of Agricultural Engineers.
- Dewit, C. T. 1965. Photosynthesis of leaf canopies. Agricultural Research Rep. 663. Pudoc. Wageningen, Netherlands.
- Doran, J. W. 1980. Soil microbial and biochemical changes associated with reduced tillage. *Soil Science of America Journal* 44:765-771.
- Douglas, C. L., Jr., R. R. Allmaras, P. E. Rasmussen, R. E. Ramig, and N. C. Roder. 1980. Wheat straw composition and placement effects on the Pacific Northwest. *Soil Sci. Soc. Am. J.* 44:833-837.

28

- Dudal, R. 1982. Land degradation in a world perspective. *J. Soil Water Conservation*. 37:345 - 349.
- Emerson, R. A. 1903. Experiments in mulching garden vegetables. *Nebr. Agr. Expt. Sta. Bul.* 80.
- Estes, E. A., W. A. Skroch, T. R. Konsler, P. B. Shoemaker, and K. A. Sorensen. 1985. Net economic values of eight soil management practices used in stake tomato production. *J. Amer. Soc. Hort. Sci.* 110(6):812-816.
- Evans, L. T. 1993. Crop evaluation, adaptation and yield. Cambridge University Press, London.
- Fischer, R. 1993. Wheat. p. 129-137. In potential productivity of field crops under different environments. IRRI, Los Banos, Philippines.
- Flanagan, D. C. and M. A. Nearing. 1995. USDA-WaterErosion Prediction Project: Hillslope profile and watershed model documentation. NSERL Report No. 10 USDA-ARS National Soil Erosion Research laboratory, West Lafayette, IN 47097-1196.
- Foster, G. R., and L. J. Lane. 1987. User Requirements. USDA-Water Erosion Prediction Project (WEPP). NSERL Report No. 1. USDA, ARS, National Soil Erosion Research Laboratory, W. Lafayette, Indiana.
- Fox, R. H., and R. J. K. Myers, and I. Vallis. 1990. The nitrogen mineralization rate of legume residues in soil as influenced by their polyphenol, lignin, and nitrogen contents. *Plant Soil* 129:251-259.
- Fryrear, D. W., A. Saleh, and J. D. Bilbro. 1998. A single event wind erosion model. *Transactions of American Society of Agricultural Engineers* (5):1369-1374.

29

- Gilley, J. E., S. C. Finkner, and G. E. Varvel. 1986. Run-off and erosion as affected by sorghum and soybean residue. *Transactions of the ASAE* 29(6):1605-1610.
- Gilmor, J. T., A. Mauromoustakos, P. M. Gale, and R. J. Norman. 1998. Kinetics of crop residue decomposition: Variability among crops and years. *Soil Sci. Soc. Am. J.* 62:750-755.
- Groffman, P. M. 1985. Nitrification and denitrification in conventional and no-tillage soils. *Soil Sci. Soc. Am. J.* 49:329-334.
- Hagen, L. J. 1991. A wind erosion prediction system to meet user needs. *Journal*

- of Soil and Water Conservation 46(2):105-111.
- Hagen, L. T., L. E. Wagner, and J. Tatarke. 1995. Wind Erosion Prediction System (WEPS). NSERL Report. No. 11. July 1995. National Soil Erosion Research Laboratory, USDA-ARS-MWA, West Lafayette, IN.
- Hendrix, P. F., R. W. Parmelee, D. A. Crossley, D. C. Coleman, E. P. Odum, and P. M. Groffman. 1986. Detritus food webs in conventional and no-tillage agroecosystems. *BioScience* 36:374-380.
- Holland, E. A., and D. C. Coleman. 1987. Litter placement effects on microbial and organic matter dynamics in an agroecosystem. *Ecology* 68:425-433.
- Hoyt, G. D. 1999. Tillage and cover residue effects on vegetable production. *HortTechnology* 9(3):351- 358.
- Hoyt, G. D, A. R. Bonanno, and G. C. Parker. 1996. Influence of herbicides and tillage on weed control, yield, and quality of cabbage (*Brassica oleracea* L. var. capitata). *Weed Technology* 10:50-54.

30

- Hoyt, G. D., and W. L. Hargrove. 1986. Legume cover crops for improving crop and soil management in the Southern U. S. *HortScience* 21(3):397-402.
- Hoyt, G. D., D. W. Monks, and T. J. Monaco. 1994. Conservation tillage for vegetable production. *HortTechnology*. 4(2):129-135.
- Hairston, J. E., J. O. Sanford, J. C. Hays, and L. L. Reinschmidt. 1984. Crop yield, soil erosion, and net return from tillage systems in the Mississippi Blacklands Prairie. *J. Soil Water Conservation*. 56:1223-1237.
- Ishii, R. 1993. Leaf photosynthesis in rice in relation to grain yield. P. 501-509. In Y. P. Absol (ed.) *Photosynthesis: Photo reactions to plant productivity*. Kluwer Academic Publishers, Dordrecht, The Netherlands.
- Ivarson, K. C., and F. J. Snowden. 1970. Effect of frost action and storage of soil at freezing temperatures on the free amino acids, free sugars and respiratory activity in Soil. *Can. J. Soil Sci.* 191-198.
- Janzen, H. H., J. B. Bole, V. O. Biederbeck, and A. E. Slinkard. 1990. Fate of N applied as green manure or ammonium fertilizer to soil subsequently cropped with spring wheat at three sites in western Canada. *Can. J. Soil Sci.* 70:133-322.
- Janzen, H. H., and S. M. McGinn. 1991. Volatile loss of nitrogen during decomposition of legume green manure. *Soil Biol. Biochem.* 23(3):291-297
- Jones, J. N., Jr., J. E. Moody, and J. H. Lillard. 1969. Effects of tillage, no-tillage, and mulch on soil water and plant growth. *Agron. J.* 61:719-721. ly grown popcorn. *Hort Science* 20:136-137.

31

- Knavel, D. E., J. W. Herron, and G. M. White. 1985. No-till popcorn performs as well as conventionally grown popcorn. *HortScience* 20:136-137.
- Knipling, E. B. 1970. Physical and physiological bases for the reflectance of visible and near infrared radiation from vegetation. *Remote Sens. Environ.* 1:55-159.
- Kusmenoglu, I., and F. J. Muchlbauer. 1998. Genetic variation for biomass and residue production in lentil: I. Relationship to Agronomic Traits. *Crop Sci.* 38:907-910.
- Ladd, J. N., and M. Amato. 1986. The fate of nitrogen from legume and fertilizer sources in soils successively cropped with wheat under field conditions. *Soil Biol. Biochem.* 18:417-425.
- Lal, R., and B. A. Stewart. 1990. Soil degradation. Need for action: Research and development priorities. *Adv. Soil Sci.* 11:331-336.

- Lane, L. J., and M. A. Nearing (ed.). 1989. Water Erosion Prediction Project Landscape profile model documentation. NSERL Rep. 2. Natl. Soil Erosion Res. Lab., USDA-ARS, Purdue Univ., West Lafayette, IN.
- Larson, W. E. 1981. Protecting the Soil resource bases. *J. Soil Water Conservation*. 36:13-36.
- Lopez, Bermudez, F., and J. Albaladejo. 1990. Factores ambientales de la degradación del suelo en el área Mediterránea. P. 15-45. In J. Albaladejo et al. (ed). *Soil degradation and rehabilitation in Mediterranean environmental conditions*. CSIC, Murcia, Spain.
- Lowrance, R., Altier L. S., Williams S. P., Sheridan, D.D., Bosch Hubbard, R. K. and Thomas, D. L. 2000. REMM. The Riparian Ecosystem Management Model. *J. Soil and Water Conservation*. 55(1):27-34.

32

Lugo-Mercado, H. M., J. Badillo-Feliciano, and F. H. Ortíz-Alvarado. 1984.

Effects of no-tillage and various tillage methods on yields of maize; field beans, and mothsoil in Southern Puerto Rico. *J. Agr. Uni. P. R.* 68:349-354

pepper grown on a

- Lynch, J. M., and L. M. Panting. 1980. Cultivation and the soil biomass. *Soil Bio. Biochem.* 12:29-33.
- Morgan, R. P. C. 1985. Effect of Corn and Soybean Canopy on soil detachment by rainfall. *Trans. ASAE* 28:1135-1140.
- Morrison, J. E., Jr., C. Huang, D. T. Lightle, and C. S. T. Daughtry. 1993. Residue measurement techniques. *J. Soil And Water Conservation*. 48(6):479-483.
- Morrison, J. E., Jr., D. C. Milbocker, W. O. Alkinson and J. H. Smiley. 1973. Transplanter modification and survival under no-tillage conditions. *Hort Science* 8:483-485.
- Morrison, J. E., Jr., R. W. Rickman, D. K. McCool, and K. L. Pfeiffer. 1997. Measurement of wheat residue cover in the Great Plains and Pacific Northwest. *J. Soil and Water Conservation*. 52(1):59-65.
- Morse, R. D., C. M. Tessore, W. E. Chappell, and C. R. O'Dell. 1982. Use of no-tillage for summer vegetable production. *Veg. Growers News*. 37(1):1.
- Moschler, W. W., G. M. Shear, D. C. Martens, G. D. Jones, and R. R. Wilmouth. 1972. Comparative yield and fertilizer efficiency of no-tillage and conventionally tilled corn. *Agron. J.* 64:229-2301.

33

- Moss, D. N., and R. B. Musgrove. 1971. Photosynthesis and crop production. *Adv. Agron.* 23:317-336.
- Muchow., R. C., and T. R. Sinclair. 1994. Nitrogen response of leaf photosynthesis and canopy radiation use efficiency in field-grown maize and sorghum. *Crop Sci.* 34:721-727.
- Mundy, C., N. G. Creamer, C. R. Crozier, L. G. Wilson, and R. D. Morse. 1999. Soil physical properties and potato yield in no-till, subsurface-till, and conventional-till system. *HortTechnology* 9(2):240-247.
- Mustaghimi, S., T. A. Dillaha, and V. O. Shenhultz. 1988. Influence of tillage systems and residue levels on run-off, sediment, and phosphorus losses. *Transactions of the ASAE* 31(1):128-132.
- Myers, Peter. 1985. *Washington Post Magazine* (Aug. 25):19.
- Nam, N. H., G. V. Subbarao, Y. S. Chauhan, and C. Johnson. 1998. Importance of canopy attributes in determining dry matter accumulation of pigeon pea under contrasting moisture regimes. *Crop Sci.* 38:955-961.

- NSERL. 1995. WEPP User Summary. National Soil Erosion Research Lab. USDA-ARS-MWA. NSERL Report No. 11. 1196 Soil Building, West Lafayette, In 47907-1196.
- Ocio, J. A., P. C. Brookes, and D. S. Jenkinson. 1991. Field incorporation of straw and its effects on soil microbial biomass and soil inorganic N. *Soil Biol. Biochem.* 23:171-176.
- OECD. 1994. (Organization for Economic Cooperation and Development). Towards Sustainable Agricultural Production: Cleaner Technologies. Paris, France: OECD.

34

- Pastor, J., and W. M. Post. 1986. Influence of climate, soil moisture and succession on forest carbon and nitrogen cycles. *Biogeochemistry* 2:3-27.
- Pearson, C. J. 1984. Introduction. Pp. 1-9. In C. J. Pearson (ed.). *Control of crop productivity*. Academic Press, New York.
- Peterson, A. E., and J. B. Swan. 1979. Universal Soil Loss Equation: Past, Present, and Future. In Peterson and Swan (ed.). *Proceedings of the soil science society of America*, Madison, Wisconsin.
- Phillips, R. E. and S. H. Phillips. 1984. *No-tillage agriculture*. Van Nostrand Reinhold, New York.
- Quinn, N. W., and J. M. Laflen. 1983. Characteristics of raindrop through fall under corn canopy. *Trans. ASAE* 26:1445-1450.
- Renard, K. G. 1992. Computerized calculations for conservation planning. *Agricultural Engineering*. July, 1992:16-17.
- Renard, K. G., G. R. Foster, G. A. Weesies, D. K. McCool, and D. C. Yoder. 1997. Predicting soil erosion by water: A guide to conservation planning with the Revised Universal Soil Loss Equation (RUSLE). USDA-ARS, Agriculture Handbook 703.
- Renard, K. G., G. R. Foster, G. A. Weesies, and J. P. Porter. 1991. RUSLE: Revised Universal Soil Loss Erosion Equation. *Journal of Soil and Water Conservation* 46:30-33.
- Renard, K. G., G. R. Foster, D. C. Yoder, and D. K. McCool. 1994. RUSLE: revisited: Status, questions, answers, and the future. *Journal of Soil and Water Conservation* 49:213-220.
- Retta, A. and D. V. Armbrust. 1995. Estimation of leaf and stem area in the wind erosion prediction system (WEPS). *Argon. J.* 87:93-98.

35

- Rice, C. W., and M. S. Smith. 1982. Denitrification in no-till and plowed soils. *Soil Sci. Soc. Am. J.* 46:1168-1173.
- Risse, L. M., M. A. Nearing, A. D. Nicks, and J. M. Laflen. 1993. Error assessment in the Universal Soil Loss Equation. *Soil Sci. Soc. Am. J.* 57:825-833.
- Ross, J. 1981. *The radiation regime and architecture of plant stands*. W. Junk, The Hague.
- Savabi, H. R., D. C. Flanagan, B. Hebel, and B. A. Engel. 1995. Application of WEPP and GIS-GRASS a small watershed in Indiana. *J. Soil and Water Conservation*. 50(5): 477-483.
- Schomberg, H. H., J. L. Steiner. 1994. Predicting crop residue distribution and cover for erosion modeling. Pp. 27-34 in the proceedings of Great Plains Agriculture Council Crop Residue Management Conference, August, 1994 at Amarillo, TX.
- Siddoway, F. H., W. S. Chepil, and D. V. Armbrust. 1965. Effect of kind, amount,

- and placement of residue on wind erosion control. *Transactions of American Society of Agricultural Engineers* 8(3):327-331.
- Soil Conservation Service. 1993. Here's looking at RUSLE. SCS newsletter dated May 14, 1993. USDA, Natural Resources Conservation Service. (Formerly the Soil Conservation Service), Washington, D. C.
- Stott, D. E. 1991. RESMAN: A tool for soil conservation education: *J. Soil and Water Conservation*. 46:332-333.
- Stott, D. E. and J. R. Barrett. 1993. RESMAN: Software for simulating changes in surface crop residue mass and cover. *Soil Science Soc. of Am. Journal* (submitted August 1993).

36

- Stott, D. E. and J. B. Rogers. 1990. RESMAN: A residue management decision support program. Public domain software. NSERL Publication #5, 266kb. USDA-Agricultural Research Service National Soil Erosion Research Laboratory, West Lafayette, IN.
- Unger, P. W. 1988. Residue management for dryland farming. P. 483-489. In P. W. Unger et al. (ed.) *challenges in dryland agriculture: A global perspective*. Texas Agricultural Experiment Station. Amarillo/Bushland, TX.
- USDA. 1989. Water Erosion Prediction Project: Hillslope Model Documentation, USDA-ARS, NSERL, Report No. 2, L. J. Lane, and M. A. Neasing (eds.). USDA-ARS, West Lafayette, Indiana.
- USDA. 1990. Agricultural Stabilization and Conservation Service (ASCS), contract data on the first nine Conservation Reserve Program sign-ups. USDA-ARS, Washington, D. C.
- VanDoren, D. M. Jr., and R. R. Allmaras. 1978. Effect of residue management practices on the soil physical environment, microclimate, and plant growth. P. 49-83. In W. R. Oschwald (ed.) *Crop residue management systems*. ASA Spec. Publ. 31. ASA, CSSA, and SSSA, Madison, WI.
- Vigil, M. F., D. E. Kissel and S. J. Smith. 1991. Field crop recovery and modeling of nitrogen mineralized from labeled sorghum residue. *Soil Sci. Soc. Am. J.* 55:1031-1037.
- Wagner, M.G. 1993. Role of cover crops in soil water and nitrogen dynamics. *Soil Sci. Soc. N. C. Boc.* 36:59-60.

37

- Wagner, M. G. and H. P. Denton. 1989. Tillage effects on grain yields in a wheat, double-crop soybean, and corn rotation. *Agron. J.* 81:493-498.
- Whitehead, D. C., D. R. Lockyer, and N. Raistrick. 1988. The volatilization of ammonia from perennial ryegrass during decomposition, drying and induced senescence. *Ann. Bot. (Fennici)* 61:567-571.
- Wiegand, C. L. H. W. Gausman, and W. A. Allen. 1972. Physiological factors and optical parameters as bases of vegetation discrimination and stress analysis P. 82-102. In *Proc. Seminar, Operational Remote Sensing*, Houston, TX. 1-4 Feb. 1972. Am. Soc. Photogram., Falls Church, VA.
- Williams, J. R., C. A. Jones, J. R. Kinisy and D. A. Spanel. 1989. The EPIC crop growth model. *Transition. ASAE* 32 (2):497-511.
- Wilson, D. O., and W. L. Hargrove. 1986. Release of nitrogen from crimson clover residue under two tillage systems. *Soil Sci. Soc. Am. J.* 50: 1251-1254.
- Wischmeier, W. H. 1972. Upland erosion analysis. In H. W. Shen (ed.) *Environmental impact on rivers*. Water Resources Publications. Chapter 15. Fort Rollins, Colo.
- Wischmeier, W. H. 1973. Conservation tillage to control water erosion. p. 133-141.

In Proc. of the National Conservation Tillage Conference. Soil Conserv. Soc. of Am., Ankeny, Iowa.

Wischmeier, W. H. 1975. Estimating the soil loss equation's cover and management factor for undisturbed land. p. 118-125. In present and prospective technology for predicting sediment yields and sources. USDA-ARS. ARS-5:40.

38

Wischmeier, W. H. and D. D. Smith. 1978. Predicting rainfall erosion: A guide to conservation planning. USDA Agriculture Handbook 537, Washington, D.C.

Woodruff, N. P., and F. H. Siddoway. 1965. A wind erosion equation. Soil Science Society of America Proceedings 29:602-608.

World Bank. 1992. Development and the environment. World Bank Development Report 1992. Washington, D. C. World Bank.

Yacob, O., and G. J. Blair. 1980. Mineralization of N-labeled legume residues in soils with different nitrogen contents and its uptake by Rhodes grass. Plant Soil 57:237-248.

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