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Research Article

Cover and Management Research on Horticultural Crops for Nutrient Management and Conservation Planning

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Introduction

Even though research and education systems have transformed agriculture from a traditional to a high technology sector, groundwater pollution from plant nutrients and soil erosion remain as major universal problems. The increased demand for food, fiber, and fuel, due to population increase, is causing marked acceleration of soil erosion and pollution. Groundwater and surface water supplies are threatened with contamination of N and P from agricultural fertilizers and animal manures.

Soil erosion is the major conservation issue on about 50% of U.S. cropland [1]. In the U.S., up to one billion tons of agricultural soil is deposited in waterways every year, and an estimated one-half of the suspended sediments in the U.S. surface water originate from agriculture [2]. 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 [3]. 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 [4]. 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 [5].

The Revised Universal Soil Loss Equation (RUSLE) is 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 [6]. This modern erosion prediction model is highly improved and updated. LAI, percent canopy cover, plant height, and growth of upper and lower biomass are important factors considered in growth parameter studies of C-factor research. Water Erosion Prediction Project (WEPP) is a process-based erosion model [7]. 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 [8]. Both these models need C-factors.

Crop residue management has been established as a valuable technology for reducing erosion and improving run-off water quality from agricultural lands [9]. Residue management has become an important component of conservation tillage systems because surface residues help reduce water loss and erosion [10]. 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 [11]. 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 [12]. Residue inputs subsequently modify soil properties important to soil quality and crop production [13]. Legume residues have increased vegetable yields when compared to grass residues [14]. Horticultural crops return less residue with low C:N ratios compared with agronomic crops [15,16]. The straw to grain ratio is 1:1 for corn, soybean, and oats; 1.5:1 for wheat, barley, rice, rye, sorghum, and millet; and 0.25 for sugarcane, potato, and sugarbeet [17].

Increases concerns over the last several decades on environmental quality have stimulated farmers to accept organic farming as an alternative. Groundwater and surface water supplies are threatened with contamination. Crop nutrients from agricultural fertilizers are the most serious and widespread source of excess nitrogen and phosphorus [18]. One of the most serious sources of nonpoint pollution is animal manures which contain organic pollutants, chlorides, nitrogen, and phosphorus [19]. Research results show lower nitrate concentrations in organic amended vegetable crops [20]. Low nitrate concentration in edible portion is very important for human health, due to its potential transformation to nitrites, which have the highest possibility to interact with hemoglobin and affect blood oxygen transportation [21]. Organic foods sales in the Unites States have more than quintupled since the late 1990s from 3.6 billion in 1997 to $21.1 billion in 2008, and now accounts for 3% of U.S. food sales [22].

Conservation tillage (CT) has become an accepted cultural practice for many seeded agronomic crops since its introduction in the 1950s. No-till was used on 25.3 million ha in the United States in 2004, an increase of 5.5% nationwide from 2000 [23]. Horticultural crops have not been studied as thoroughly as agronomic crops in CT experiments [24]. Direct seeded vegetables such as sweet corn and squash can be planted easily by current no-till seeders designed for agronomic row crops [25]. CT improved or maintained yields similar to conventional tillage in tomatoes [26], field beans and peppers [27], potatoes [28], cabbage and broccoli [29], and lima beans [30].

Alcorn State University entered into a Cooperative Research and Development Agreement (CRADA) with the Natural Resources Conservation Service (NRCS) of the United States Department of Agriculture (USDA) in 1988 to conduct C-factor (cover and management) research on horticultural crops. The main objectives of this research are (a) to collect growth and residue data of horticultural crops that are used to populate databases needed to develop C-factors in RUSLE, and used in databases for other erosion prediction and natural models, and (b) to conduct conservation research on horticultural crops raised on organic, no-till, and conventional plots for nutrient management, conservation planning, and outreach programs.

Materials and Methods

The data collection procedures for the C factors are comprehensive and require a series of very technical procedures. The procedures were established by USDA-NRCS and USDA-ARS scientists in collaboration 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 erosion prediction models, residue decomposition studies, nutrient management, and conservation planning. Destructive harvest study is carried out every 15 days from the date of emergence until the final harvest on each crop to study biomass development. 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 (LAI) and percent canopy cover. The ideal time to record these readings is between 10:00 a.m. and 2:00 p.m. Various residue measurement techniques are currently in use.

Fresh plant residues collected from the field immediately after final harvest are cut into small pieces and 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:N ratio using Elemental Analyzer. Based on soil tests for nutrient requirements, animal and forest wastes are applied on research plots following the federal regulations. Soil core samples of 100 cm deep are analyzed for soil physic-chemical changes. Organic fruits are analyzed and compared with inorganic fruits for yield, antioxidants, minerals, and vitamins. Weather information is recorded by a computerized weather station and assembled as a database. C-factor data gathered in the field and laboratory are compiled and stored using a data base management program called SEIMS (Soil Erosion Information Management System).

Results and Discussion

The information generated is used around the world for erosion prediction models, including RUSLE, WEPP, and WEPS, and nutrient management and conservation planning. The center has developed organic farming systems with animal and forest wastes to raise shallow-rooted fruit crops, such as blueberries, on heavy soils and succeeded in increasing the yield, its Vitamin C, and antioxidant content [31,32]. Continuous application of animal and forest wastes for a decade in the basins of fruit crops shows that there is high concentration of nitrate-N and P in the surface layers of soils, but there was no trend in enrichment of these polluting elements in the lower layers. The leaching of N and P into subsurface layers from inorganic fertilizers is highly significant. No pathogenic organism from organic manures was found in fruits. Soil compaction was always higher in inorganic plots with lower soil moisture content, but the compaction was lower in organic plots due to higher level of organic matter content [16,31,33]. The results suggest that the controlled application of animal manures in basins of perennial fruit crops of orchards and vineyards can be an agronomically and environmentally sound practice. Sub-surfaced residues of both shoot and root decomposed faster than surfaced residues. Results show that decomposition of crop residue is a function of C:N ratio and its placement. The decomposition rates of both root and shoot residues are negatively correlated with the low C:N ratios [34].

Conclusion

The enormous amount of data collected on over 45 crops with over 140,000 readings covering leaf area index (LAI), percent canopy cover, yield, lower and upper biomass development at every 15 days of growth, rate of residue decomposition for 180 days, C:N ratios of samples of destructive harvest at various growth stages and on decomposing residues, carbon buildup, and no-till, organic, and inorganic crop production practices made this research center the largest C-factor databank on horticultural crops. These studies help identify the quantity of carbon and nitrogen returned by the preceding crop to the succeeding crop, soil conserving and depleting crops, best time to clip down the upper biomass for maximum economic returns and minimum soil erosion, most favorable time to apply or reduce top dressing based on residue decomposition, effect of no-till cropping system in carbon and plant nutrient buildup, and role of animal and forest wastes in organic production on heavy soils. This invaluable information helps prevent soil erosion, avoid groundwater pollution from crop nutrients, and develop scientific conservation planning on horticultural lands. In conclusion, it is suggested that it is very important to control the placement, type, amount, and form of the animal waste and crop residues incorporated into the soil for nutrient management and conservation planning.

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Conflict of Interest

No conflict of interest.

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