STEEP Impact Assessment

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STEEP
Solutions to Environmental and Economic Problems

STEEP Impact Assessment

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On the cover:

(Top Left) Severely eroded cropping field in the Palouse region of eastern Washington due to rain on frozen soil after use of conventional tillage systems, prior to STEEP research, early 1970' (D.K. McCool photos).

(Top Right) Results of STEEP research: Extension Specialist Roger Veseth walking in a field of direct seeded winter wheat into fertilized spring wheat residue, ca. 2002.

(Bottom) Direct seeding winter wheat into spring wheat residue, 2005.

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A report prepared by the STEEP Coordinating Committee

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Preface

The 30-year-old STEEP (Solutions to Environmental and Economic Problems) research and education program has gained national reputation as a landmark in conservation development for the Pacific Northwest. The basic strategy for STEEP was a systems approach that addressed all of the characteristics of conservation farming from planting to harvesting. STEEP's primary goal was to bring about a major reduction in soil erosion of the region's 8 million acres of steep cropland that produce some 13% of the nation's wheat supply and 80% of its specialty soft white wheat for export.

By the mid-1900s, erosion had taken its toll of prime topsoil from wheat fields and was becoming a serious environmental and economic threat to Northwest agriculture. Through the successful development of conservation technology and farming systems, typical soil loss rates of 20 tons/acre/year in prior times have been reduced to a tolerable 5 tons/acre or less per year without financial hardship to wheat growers and with long-term benefits of improved soil, water, and air quality. The STEEP accomplishments were a culmination of research by multi-state (Idaho, Oregon, and Washington) teams of university and USDA scientists utilizing a multi-disciplinary approach. Through participation by wheat growers and university Extension scientists (or staff) collaborating across state borders, these results have been widely applied to reduce the severe erosion. The STEEP program would not have been as successful without the unwavering support of grower associations, private industry and federal and state partners.

Though STEEP can boast success, much more needs to be done to stabilize and protect the Northwest environment, natural resources, and productivity to ensure a sustainable agriculture for the future. Direct seed systems are just now being adopted by growers, but without continued STEEP research funding, the adoption will falter. The STEEP program is positioned to provide research and oversight capability to meet the ever-changing needs for successful conservation farming throughout the Northwest and other parts of the nation for the years ahead. The STEEP program is a proven organization for positioning Northwest agriculture to answer the new demands to produce Feed, Food, Fiber, and Energy for the 21st Century.

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Introduction

The Chairs of the STEEP research program were asked by the USDA for an assessment of the impact of its agricultural research and education activities over its 30 years of existence. The rationale was to evaluate the extent to which program goals were achieved and the return from money spent.

STEEP was launched in 1976 with a mandate to establish a cooperative effort between the state agricultural experiment stations of Idaho, Oregon, and Washington with the USDA Agricultural Research Service for developing a new approach for controlling erosion and water quality degradation focused mainly on the high precipitation Palouse region (Oldenstadt et al. 1982). However, the studies covered an area of about 8.3 million acres of prime wheat land, including low and intermediate precipitation zones encompassing parts of the three Pacific Northwest states.

Since inception, the U.S. government's total investment in STEEP has been approximately $15 million in grants to the state experiment stations and supplemental funding to several USDA/ARS Units in the three-state area. However, a unique feature of the special grant model was its power to draw base resources from departments and other institutional units and contribute them towards high priority research. As a result, the amount available to research and education was at least double that allocated in direct federal support for the program.

Tillage on severely eroded slope in the Palouse region, prior to STEEP research 1970s (D.K. McCool photo).

The Palouse, noted for its capacity to produce world record-yielding wheat crops, has experienced some of the highest erosion rates in the US since farming began in the 1880s. Annual losses from its croplands amounted to millions of tons of soil annually.

Conventional seeding in tilled and fertilized summer fallow, ca. 1975.

Historical annual erosion rates were estimated at 10 to 30 tons/ac/yr (approximately 1/8 inch of topsoil) with conventional farming practices (USDA 1978). By some estimates this is equivalent to three-fourths ton of topsoil eroded for each bushel of wheat produced. Approximately a third of the eroded soil is washed into the region's water bodies which constitutes an incalculable ongoing environmental cost. Erosion is not just a polluter; it is an accelerating process that has denuded large acreages of topsoil and, thus, reduced the capacity of the once-rich farmland to sustain economical production. The cause of erosion is a combination of factors including 1) a winter precipitation climate with high potential for frozen soil runoff; 2) steep and irregular topography that does not lend itself to conventional structure or landscape modification practices to control erosion; and 3) a predominant winter wheat cropping system that leaves the soil nearly bare during the winter rainy season. Traditionally, two thirds of the erosion has occurred from fall-seeded wheat fields that lacked protection over the winter.

By the 1970s, hindsight made it clear to stakeholders that agriculture in the wheat lands was on a disaster course and that major changes in farming practices were urgently needed to reduce erosion rates and water pollution. The fundamental concept was that the three states must combine their resources and generate a multidisciplinary, regional research effort to develop new techniques and strategies for soil erosion control. STEEP, constructed as a special grant request guided by input from growers, researchers, extension specialists and conservationists from the three states, was considered the best approach for solving these broad environmental and economic problems.

Impact Assessment

Assessing the benefits of agricultural research and education is an indirect science not easily accomplished by any specific procedure. The reasons are multiple. Single research project results are not often directly related to a broader benefit; research accomplishments come about in small steps, often with negative findings; and the research benefits frequently accrue years after the result. The willingness to learn from failures as well as successes is a key component of effective agricultural research for development. Impact assessments and evaluations must recognize that “failure” may actually represent “work in progress” (Morris et al. 2003).

Most procedures to conduct a research assessment have been developed by economists and involve multiple methods of econometrics. However, these readily acknowledge the lack of economic values available for many agricultural effects, and, in particular, those with long-term effects on the natural resources where economics becomes general and intractable. In this case, other related parameters and data such as sustained production and reduced degradation become the indicators of choice to document changes and improvements (Morris et al. 2003).

STEEP Methodology

The focus of STEEP was to develop and encourage grower adoption of new, economically feasible conservation cropping systems based on principles of soil surface and crop residue management that were proven to be effective for erosion control (Oldenstadt et al. 1982). The core strategy was to shift to reduced- and no-till farming, and away from moldboard plow tillage that was universal with conventional farming. Historically, moldboard plowing was the primary operation to manage heavy residues from high yielding wheat crops, control weeds, and prepare seedbeds. However, plow-based tillage was at the root of the erosion problem because it cleared most of the cover that had been effective for slowing runoff and soil loss from the land.

On the other hand, changing from the well-established moldboard plow and intensive tillage methods to conservation systems involved a host of unknowns with risks that could cause financial disaster to the farmers if they incurred increased costs and/or decreased crop yields. A change of this magnitude would require new approaches for everything from crop residue management, crops and rotations, and sowing methods, to pest control and fertility management. Economic viability and social impacts of the new farming systems would also need to be considered. If the STEEP plan had some level of success there should be linkages, in time, of its accomplishments with actual or potential reduced soil erosion; improved soil, water, and air quality; enhanced farm profitability; and economic stability.

Several surveys were conducted by STEEP projects to assess perspectives on grower attitudes and behavior regarding aspects of conservation farming (Carlson and Dillman 1999). This survey information also served to predict relative changes in the use of conservation practices. In addition, there is ample credible knowledge within the farming community to document changes in farming practices that occurred during the past thirty years to establish linkages of these with STEEP accomplishments.

The following sources of information were used to document the impact of the STEEP program:

1. **STEEP accomplishments.** Documentation includes various published reports such as scientific papers from STEEP research or related sources, and two major reviews of the program—both published in book form. One is *STEEP—Conservation Concepts and Accomplishments*, published in 1987 by the University of Idaho, Oregon State University, Washington State University, and the USDA Agricultural Research Service. The other is *Conservation Farming in the United States—Methods and accomplishments of the STEEP program*, published in 1999 by CRC Press.

2. **Interviews with wheat growers.** Information on changes in farming practices and related observations was obtained by the authors in 2006 from individual interviews with nine prominent local producers. These included growers in Washington (four in the greater-than-18-inch-rainfall zone, two in the 16–18-inch-rainfall zone), Oregon (one in the 16-inch-rainfall zone, one in the 12-inch-rainfall zone) and Idaho (one in the 22-inch-rainfall zone), all with personal farming experience that more than encompassed the past thirty years in the STEEP impact area. The interviews lasted two to three hours each. By consolidating the management knowledge of their farm and others in their locality, we documented actual experiences of new technological developments, changes in practices, and expert opinions relating to soil erosion and water quality during the STEEP era. While the sampling was not

Two-pass seeding of winter wheat into fertilized spring wheat stubble, 1995.

rigorous, the trends that emerged were clear. The growers identified changes in cropping systems, rotations, crop yields, tillage, use of farm equipment and farm size.

3. **Erosion estimates by USDA-Natural Resources Conservation Service with the Revised Universal Soil Loss Equation, Version 2 (RUSLE2) prediction model.** The agency provided additional insights and data about changes in conservation practices and resource impacts. They related changes to both the USDA farm programs and the science and knowledge required to deliver recommended practices to farm fields. The impacts on soil erosion of applying improved conservation practices were evaluated using the latest versions of the RUSLE2 soil erosion model.

4. **Independent assessments on soil and water conditions and trends in the STEEP impact area.** Independent assessments came from published information on monitoring studies that compared pre-1970 trends in erosion and climate and water quality with those of recent times.

STEEP Accomplishments

The following are STEEP accomplishments that have played a major role in advancing conservation during the first thirty years of its life.

1. **Early research on fertilizer application methods established yield advantages and improved use efficiency of band placement over broadcasting fertilizer in reduced- and no-till systems.** The superiority of band placement led to the design of drill openers that simultaneously sow and place fertilizer in proximity and generally below the seed row. Development of new and improved no-till openers focused on minimal soil disturbance, residue clearance, reduced draft, uniform seeding depth and a firm seedbed. Research outcomes included: the double-furrow concept (very narrow fertilizer opener positioned below a wider seed furrow to move dry soil aside); parabolic opener to place liquid or dry fertilizer apart from the seed while featuring low soil disturbance; low power requirements; and good residue clearance. Another outcome was the twisted shank opener that enabled uniform seeding depth for improved seed germination, low soil disturbance, and reduced draft requirements. These prototypes and modifications of them are now incorporated in the design of openers in most no-till drills (Peterson 1999; Hyde et al. 1987; Koehler et al. 1987; Payton et al. 1985; Wilkins et al. 1983; Veseth 1985). The STEEP research also attracted international expertise in opener design with collaboration resulting in introduction of the Cross-Slot opener with capability to sow through heavy residue without plugging, while maintaining uniform seeding depth (Baker and Saxton 2007).

2. **The shank-and-seed concept developed by STEEP was the forerunner of the 2-pass low-cost reduced tillage seeding system for winter wheat used widely by Palouse growers since the 1990s.** The first version, the Chisel-Planter incorporated fertilizing and sowing in a single operation. The second version, the Chisel-plus-Drill, which followed the principles of the Chisel-Planter, met the need for a low-cost seeding system that could be easily duplicated by growers. It consisted of a chisel plow equipped with a fertilizer applicator followed by a grain drill with double disk openers. Adaptations to this system have been constructed by commercial firms and growers but the improvements and modifications follow from the original concepts developed by STEEP. In addition to eliminating tillage costs, the 2-pass system leaves the soil surface with 65 to 70% of the residue and moderate-sized clods that are excellent for erosion control (Peterson 1999).

3. **STEEP and the USDA's Integrated Pest Management (IPM) Project jointly pioneered development of a reduced/no-till grain production system that successfully controlled weeds, satisfied conservation compliance, and was more profitable and economically**

less risky than the traditional conventional system. Historically, lack of weed control and difficulties with residue management were major deterrents to the adoption of reduced tillage for erosion control, particularly in the intermediate and high precipitation areas. These inevitably led to reduced crop yields compared with the established intensive tillage methods. The success of the conservation production system is attributed to its integration of a diverse crop rotation, limited tillage, and judicious use of herbicides for effective weed control. Economic viability was achieved by higher yields in dry years, less damage to winter wheat in severe winters, and increased disease resistance to crops growing in the high residue seedbeds. The USDA's NRCS and Cooperative Extension relied extensively on the outcomes of this research in developing farm plans to meet conservation compliance provisions in the 1985 and 1990 Farm Bills. Results of the study were also used by the US EPA in establishing strategies for pesticide use and reduction policies on agricultural lands. The NRCS estimated that in 1995 half of the growers in the Palouse were using some aspect of the STEEP/IPM production system research on their farms (F. L. Young et al. 1994, 1994, 1996; D.L. Young et al. 1994, 1999).

4. **Research established that volunteer cereal and weeds between crops serve as a "green bridge" host in untilled soil for Rhizoctonia root rot, a serious disease of wheat and barley.** As the interval from fall to spring for application of glyphosate was decreased, or from 3 weeks to 3 days before no-till sowing into crop stubble in the spring, the severity of *Rhizoctonia* root rot increased and grain yield decreased. Until discovered, this unexplained effect limited progress with no-till for spring-seeded wheat and barley. Once understood, the "green bridge" effect could be negated in no-till by timing of volunteer and weed kill with herbicide or adjustment of other practices (Smiley et al. 1992).

5. **Risks with early fall planting to provide maximum vegetative ground cover over winter have been reduced by development of soft white winter wheat varieties with increased resistance to stripe rust and some root diseases that have been major impediments to this proven erosion control practice.**

6. **Positive yield correlations of wheat genotypes grown on no-till and conventional tillage in screening tests showed that there is little or no difference in yield rankings of varietal performance between the two production systems.** Early attempts with conservation tillage produced a range of crop yields—almost all less than that achieved with conventional tillage. The reasons were not apparent, and many speculated that it was the result of poor performance by some wheat varieties. Several years of research with careful management showed that yields were similar among varieties, thus the need to conduct separate breeding programs for each system was no longer justified (Allan and Peterson 1987).

Two-pass seeding of winter wheat into fertilized spring wheat residue, 1995.

7. **The Revised Universal Soil Loss Equation (RUSLE) developed with Northwest region parameters served as a base tool for planning conservation practices at the federal policy and farm levels.** The model outputs from tillage and cropping practices were used by federal agencies to establish guidelines for meeting conservation compliance requirements in the 1985 and 1990 Farm Bills. The guidelines were also used to aid farm planners and growers in designing practices that would reduce water erosion and be economically attained (McCool and Busacca 1999).

8. **RESMAN (RESidue MANagement), a crop residue decomposition model, was developed to simulate the rate of residue mass loss, both surface and buried, based on environmental factors (precipitation and air temperature) and residue composition (carbon and nitrogen contents).** Residue decomposition is a key factor in residue management and must be accounted for in calculations of cover for erosion control under different tillage and cropping systems. The theory and equations used in RESMAN have

been incorporated in USDA's erosion models including RUSLE and RWEQ (revised wind erosion equation) and implemented beginning in 1995. The RESMAN model has also been incorporated in USDA's upcoming prediction models WEPP (water erosion prediction project) and WEPS (wind erosion prediction system) (Stroo et al. 1989; Elliott et al. 1999).

9. **STEEP surveys in the Palouse indicated that grower attitudes about conservation and erosion control, and income level were significant predictors substantiating an increase in the adoption of erosion control practices in 1990 compared with an identical survey in 1976.** The survey further indicated that absentee landlords are not an obstacle to acceptance and adoption of conservation practices on the farm; instead it is most related to the characteristics of the new technology itself (e.g., no-till). Thus, during this time there has been a positive change in grower attitudes towards erosion control and implementation of control practices. Kinship farming and individual grower characteristics both are important positive factors in the adoption of erosion control practices. Growers were more inclined to relate with peers or innovators and utilize an information mode for seeking ideas in developing and adopting conservation technology than to use a "one-way trickle down" or hierarchal communication process. This suggests the importance of identifying opinion leaders among growers and enhancing their role in the adoption process (Carlson and Dillman 1999).

10. **The STEEP extension and education project played an extraordinary role in increasing the awareness and adaptation of conservation technology through timely publications, conferences and workshops, on-farm testing and field demonstrations, and grower conservation organizations.** Education and outreach materials include newsletters, popular articles, audiovisuals, and presentations at meetings and field activities. The STEEP website (http://pnwsteep.wsu.edu/) is readily available to researchers and farmers and contains the STEEP Pacific Northwest Conservation Tillage Handbook series (initiated in 1989; containing over 160 articles on conservation tillage; and with a distribution list of over 2,800 subscribers) (Veseth et al 1989–2007), On-Farm Test results, the PNW-Direct Seed e-mail list serve, Conservation tillage resources and links to other conservation tillage and partner websites. The on-farm testing program brought growers and extension specialists/researchers together to analyze and test firsthand the performance of new STEEP findings or technologies on farm fields and thus, aid and accelerate the adoption process. Likewise field demonstrations provided opportunities for growers to observe research and commercial reduced-and no-till seeding equipment operating in the field, and subsequent performance of crops and cropping systems. A major accomplishment of STEEP extension and education was leadership in development of the Northwest Direct Seed Cropping Systems Conference (NDSCSC), an annual event since 1998 attended by an average of 600 growers, where updates on local, regional, and international perspectives on conservation are addressed. STEEP is also credited with helping organize the PNDSA (Pacific Northwest Direct Seed Association), a spin-off of the NDSCSC, which is a grower-based organization (currently about 300 members) dedicated to increasing economical direct seed (reduced and no-till) farming systems in the Pacific Northwest (Veseth and Wysocki 1999).

11. **Cropping systems research in the low precipitation zone prone to wind erosion showed that spring wheat–chemical fallow rotation and annual no-till spring cereal cropping were generally less profitable than minimum till winter wheat–fallow. An exception was an experiment where net income from continuous no-till soft white spring wheat was equal to soft white winter wheat-fallow.** Annual no-till cropping with surface residue management essentially eliminates wind erosion in the dry-farmed wheat lands. However, risks with drought make annual

Two-pass seeded winter wheat into spring wheat residue, 2005.

cropping less competitive economically than the more erodible winter wheat–fallow cropping system. Minimum-till fallow was shown to reduce fine dust emissions that cause health risks by 54% compared with clean -till fallow, and to equal its profitability, but in some situations may not achieve the 30% minimum surface residue requirement for adequate wind erosion control. With existing farm economics, if environmental benefits of improved air quality, resource protection, and lower health risks associated with conservation are factored into the payoff, growers would have more incentive to shift from clean tillage to chemical fallow or annual no-till cropping systems (Thorne et al. 2003; Janosky et al. 2002; Juergens et al. 2004; Lee 1998; Papendick 2004; Young, D.L. 2001).

12. **STEEP collaborated with the Columbia Plateau PM_{10} wind erosion project in developing the minimum till undercutter method, a new economically feasible strategy of summer fallow farming that causes little surface soil disturbance for excellent control of wind erosion during the 13-month fallow period.** No agronomic advantages are lost in switching from conventional tillage fallow to the undercutter method. Due to recent higher energy and reduced herbicide costs, the undercutter method returns more net income to the grower than conventional tillage methods that are highly susceptible to wind erosion. The USDA/NRCS is convinced of the environmental and economic payoff of the undercutter method. In 2006 it made a $906,000 grant available to the Washington Association of Wheat Growers through the USDA's Conservation Incentive Program (CIP) to assist dryland growers in 14 counties in Washington and Oregon with demonstrating and advancing the undercutter technology for winter wheat–fallow farming in the inland Northwest (Washington Association of Wheat Growers, Ritzville, Washington, personal communication, 2006; Schillinger 2001; Papendick 2004).

13. **STEEP has had a profound impact on Agricultural Policy and Implementation for the Pacific Northwest.** The Food Security Act of 1985 (FSA) played a significant role in fostering soil conservation by linking eligibility for commodity payments with incentives for erosion and water quality control. It required growers with highly erodible lands to develop approved conservation plans by 1990, and to retain eligibility for all USDA farm programs the plans were required to be fully implemented by

Direct seeding of winter wheat into spring wheat residue, 2005.

1995 (Walker and Young 1999). Because STEEP was already well established in 1985, its research was positioned to provide fundamentals for management practices that growers could or already had adopted to meet the compliance provisions of the law. The USDA's Soil Conservation Service (now Natural Resources and Conservation Service) and Cooperative Extension had at their disposal STEEP research on field-tested conservation cropping systems, early fall planting, low-cost reduced-tillage or no-till seeding systems and residue management methods for information and options in farm planning (Michalson 1999).

With the pending outlook that the World Trade Organization will eliminate wheat subsidies in the future, and with the growing emphasis on environmental protection, STEEP research has prepared growers to strengthen their farm economies by participating in programs that reward them for providing environmental services as well as conservation. STEEP also conducted research on the conservation, land retirement and water quality provisions, proposals for policy reform, and commodity policy impacts on conservation in the Food Security Act (Walker and Young 1999). The objective of the research was to project the potential effectiveness of the policy and changes needed for achieving regional environmental and economic goals. This work revealed that a shortcoming with the 1985 FSA for the Northwest was that support payments were limited to existing program crops with high erosion potential. That is, there was no flexibility for growers to use hay, edible legumes or green manure crops in rotations that reduce erosion because doing so would reduce base acreages of program crops. Consequently the

Farm Bill was amended in 1990 to allow growers to plant 15 to 25% of their base acreage to other crops without losing acreage for future support payments. In 1996 the concept of base acreage was eliminated (Walker and Young 1999). Another regional analysis revealed that multi-county bid caps for enrollment in the Conservation Reserve Program resulted in inequities and low cost effectiveness of the program with loss of net income to growers in the more productive but more erodible Palouse but a gain in net income in the drier regions to the west where the potential for water erosion was less. Other research indicates that policies linked to environmental goals are most acceptable if they allow profitable crop production (Painter and Young 1993).

Grower Evaluations

The grower evaluations of farming changes based on the interviews are as follows and are not restricted solely to developments and changes in conservation practices.

Starred items (*) indicate direct linkage with STEEP accomplishments.

Double starred (**) items indicate impacted by or indirectly related to STEEP accomplishments.

1. ***Use of the moldboard plow has declined.** Prior to the 1980s the plow was universally the primary tillage tool for residue management, weed control and seedbed preparation. Its long-term detrimental effects included disrupting the natural structure of the soil and the beneficial biological soil life in it, making the soil more vulnerable to erosion and accelerating the oxidation of its organic matter. Both contribute to the insidious decline of soil productivity and quality that are difficult and costly to restore. In recent years, less disruptive, surface-residue-conserving equipment (e.g., chisel plow, field cultivator) has replaced the plow, eliminating its use following legume crops and reducing its use by 80 to 90% after spring cereals and 40% after winter wheat.

2. ***Burning of winter wheat stubble and summer fallow has been significantly reduced.** It was estimated that in the high precipitation areas in the 1970s, with about 47% of the acres in winter wheat, about 36% of the stubble was burned before plowing. Burning winter wheat stubble was reduced to about 22% of the acreage in 1990 and to near zero in 2005. Similarly, in the intermediate precipitation zone with 50% of the cropland acreage in winter wheat in the 1970s, approximately 20% was burned. With 40% in winter wheat in the 1990s only about 13% of the stubble was burned compared with near zero in 2005. Burning stubble was (and is) not practiced in the low precipitation areas because of low residue amounts. Approximately 13% of the cropland acreage in the high precipitation zone was fallowed in the 1970s; this dropped to about 6% in the 1990s and to near zero in 2005. In the intermediate precipitation zone, cropland acreage in fallow changed little, from about 24% in the 1970s and 1990s to about 20% in 2005 but with an increase in chemical fallow in recent years. Fallow acreage remained from 46 to 48% in the low precipitation zone over the past 30 years. However, there has been an increase in reduced- and delayed-tillage fallow in the past 15 years. Introduction and wide-spread use of glyphosate herbicide has enabled the conservation efforts by replacing tillage for weed control.

3. ***Reduced tillage has become a standard practice on most farms.** During the 1970s, winter wheat planted after a pulse crop, spring cereals, or winter wheat required 4 to 5 passes across the field, and a spring crop after winter wheat 8 or more passes to complete the sowing operation. Today, most growers have reduced tillage ahead of seeding by eliminating and/or combining operations. One system that started in the mid 1980s and has become popular with winter wheat following a legume is a two-pass operation, i.e., on untilled ground a cultivator with shanks to band fertilizer is followed by sowing with double-disk drills. By 2005 many farmers were doing this in one pass. With spring cereals following winter wheat, the field may be fall-chiseled, fertilizer banded in the spring with a cultivator, and seeded with a double-disk drill (3 operations compared with 5 or 6 with conventional farming). Legume crops (pea, lentil, garbanzo beans) following winter wheat or a spring cereal usually require 4 to 5 operations (8 to 10 for conventional farming), with a reduced tillage system to manage cereal residues and condition the ground surface for harvesting the crop. Today an increasing number of growers are using a one-pass seeding system (complete no-till) as they find the soil more mellow after several years of practice. Spraying to control weeds are extra operations in both the one and two pass systems but these do not disturb the soil.

4. ***Most growers have shifted to longer crop rotations.** Winter wheat–dry pea with intensive tillage was the dominant cropping system during the 1970s practiced on 90% of the farms in the Palouse. In the mid-1980s many growers shifted to a reduced-tillage, three-year winter wheat–spring cereal–grain legume (following results of the STEEP IPM study), or conservation tillage fallow in lower rainfall zones, or even longer rotation, thereby reducing the frequency of winter wheat. Advantages of the longer rotation are improved and more economical pest control (weeds, diseases, and insects) which, along with the rotational effect, results in higher yields and more stable farm income in the long-term. Longer rotations also tend to spread the workload during planting and harvesting and in this way allow for timely farm operations and reduce machinery and labor requirements.

5. ***No-till is on the increase and the trend is likely to continue.** New knowledge developed by scientific effort and grower innovations, along with education and improved implements, have removed some of the early concerns and limitations to use of no-till. For example, elimination of the "green bridge" by spraying herbicide early enhanced the success of no-till by reducing root diseases that killed emerging crop seedlings in no-till fields recently sprayed for weed control. Longer crop rotations improved weed and disease control and required less use of herbicides in reduced- and no-till systems. New and improved types of no-till drills have been developed, although adoption by growers is slow. The main factors limiting adoption by more growers appear to have been lower yields experienced by some growers with high surface residue farming, yield instability, lack of know-how and change-over costs in shifting to no-till from conventional farming. Education, along with technological improvements, reduced costs of equipment, and drastically reduced fuel use will help to remove this barrier.

Primary spring tillage plus liquid aqua nitrogen injection with a V-sweep undercutter implement in the winter wheat-summer fallow region, 2005.

6. ****Plant breeding, along with improved genetics and crop management, have increased cereal yields but not grain legume yields.** Grower estimates indicate that winter wheat yields today with reduced tillage and timely management have increased an average of 40% compared with yields 30 years ago. Winter wheat yields in the higher precipitation areas commonly exceed 100 bu/ac. The increased yields are attributed to improvements through plant breeding and genetics, availability of more effective and selective herbicides for weed control, improved seed placement and fertilizer banding technology and improved water conservation with conservation tillage. Spring wheat yields have also increased to as high as 85 bu/ac today compared with peaks of 60 bu/ac 30 or more years ago, much for the same reasons as winter wheat. Yields of grain legumes have remained more or less stable. Some growers believe that with legumes improvements in yield capability are offset by a declining soil quality.

7. **Horsepower has increased markedly on most farms since the 1970s.** Farm tractor size in the Palouse has increased from 50–150 horsepower common in the 1970s, to 300–450 horsepower today. Virtually all machines are equipped with rubber tires or tracks. Increased horsepower has made combining operations possible—resulting in fewer passes across the field. The larger equipment and higher speeds have also resulted in more acres covered with less labor/acre. This improves overall cost efficiency. It has also made possible more timely operations which are especially important on larger farms. Increased horsepower has been favorable to conservation on large farms because of the higher power requirements necessary for one- or two-pass seeding systems to cover large acreages.

8. ****Farm size has increased with 50% fewer operators today than in the 1970s.** Presently, all of the 500 acre farms of the 1970s that were full-time operations have disappeared—by either going out of business or increasing farm size. Farms 1000 acres in size are on the borderline of staying in business today. The mainstays of

growers staying operational with today's cost of production and prices are increasing efficiency (e.g., cutting operations, reducing input costs), maintaining high yields and high production volume of crops with the best prices, and participating in government farm programs. Opportunities for maintaining or increasing high yields depends heavily on continued flow of new technologies including improvements in crops and crop culture (breeding programs) and new innovations and improved efficiencies in farm operations. Farms grow in size through purchase or lease of additional land, or consolidation of kinship holdings. Conservation technologies have reduced the number of field operations to grow crops, thereby enabling an operator to farm more land. The view is that farm size will continue to increase due to economic pressures and government programs that foster large operations.

9. ***Soil erosion in the Palouse has decreased during the past 30 years and especially in the past 10 as adoption of conservation practices continues to increase.** A significant observation was that county and state highway road ditches alongside farm fields do not fill with sediments making cleaning less frequently needed than in earlier times. More fields are covered with residue or are rougher on the surface as a result of limited or no tillage with winter wheat planting, compared with clean tilled seedbeds of the 1970s when erosion was more severe. Fields that are not sown to winter wheat are left rough tilled or untilled over winter and do not erode. As a result of conservation tillage, rills and gullies are less evident on increasing numbers of fields which indicates reduced erosion rates.

10. **Coping with large amounts of straw from high wheat yields is an obstacle in the adoption of conservation practices.** With current economics, most farm operations depend on high wheat yields to make a profit and stay in business. The high grain yields from today's varieties also result in high straw yields. For many growers, practicing conservation becomes more difficult with straw in excess of that necessary to protect the soil from erosion. Mechanical removal of excess straw is costly without any financial return; burning is not a conservation option and is environmentally unsound. Some producers are able to manage with no-till in high surface residue situations but the experience is limited, cost estimates are unavailable and the results have not been experimentally confirmed. Grower consensus is that residue management (mechanical methods, breeding for shorter straw cereals, or straw that decomposes faster) with high yielding wheat varieties should be given high priority in USDA and university conservation and environmental quality research.

Direct seeding of winter wheat into spring wheat residue, 2005.

11. ****Government farm programs with incentives that promote conservation and environmental quality goals are attractive to growers but, because of under-funding, participation is too limited to have a significant regional impact in achieving soil and water quality objectives.** For example, growers regard the USDA Conservation Security Program to have well-planned objectives and incentives to achieve stewardship goals. However, the funding in most areas is restricted to only a few watersheds in a region. This not only places strict site limits on eligibility but causes dissension among the broader population of producers and non-eligible neighbors with similar interests in increasing conservation treatments on their farms. Other programs that pay for environmental services are often in the same situation: too few dollars for widespread improvements in conservation. Growers in general find satisfaction with farm programs that reward them for implementing practices that provide environmental benefits, provided that these do not cause a loss of net income.

12. ***Soil quality improves with continuous reduced/no-till systems.** Growers practicing continuous reduced/no-till consistently observed improvements after several years in soil properties relating to tilth, cohesiveness, and organic matter accumulation near the surface. Topsoil was described as mellow—easing placement of seed and fertilizer; draining better

and firming—allowing equipment on the field earlier in the spring; more earthworm-rich—making the untilled soil more porous and better aerated; and having decreased runoff after heavy rains and snowmelt with greater resistance to erosion and darker topsoil. As these properties became established, growers indicated that they are reluctant to change cultural methods for any reason back to the "intensive tillage way" of farming.

RUSLE2 Calculations

Dominant cropping and soil management practices were selected from the information obtained in the grower interviews and grouped according to average annual precipitation zones, i.e., high (20–22 inch), intermediate (16–18 inch) and low (12–15 inch) for each of three years within the study period: 1975, 1990, and 2005 (Table 1). Listed for each of these years in a climatic zone are typical rotations and farming operations used by interviewed growers and their neighboring growers. In addition, an estimate was made for the percentage of growers in the sample area using each rotation that provided a weighting factor to the conservation effect. Table 1 was reviewed by regional USDA/NRCS staff familiar with the sampling sites to confirm accuracy.

The most recent version of RUSLE2 with parameters fitted for Pacific Northwest conditions was applied to estimate long term annual sheet and rill erosion (the most dominant types of water erosion), the soil conditioning index (SCI), and the soil tillage intensity rating (STIR) associated with each rotation and management system. The abbreviated management practices listed under "Farming operations" are sequenced as a system for each rotation in the RUSLE2 input files. Runs were made for each year and rotation while the base conditions of climate, soils and topography for each precipitation zone were held constant.

Farmer involvement and outreach programs are integral to the success of the STEEP program.

The SCI measures the effects of management on the state of soil organic matter. It considers soil organic matter balance as influenced by crop production, climatic decay, tillage, and erosion. A value of -1 is highly degrading to the organic matter, 0 is neutral gain/loss, and +1 is very beneficial to organic matter gain. The STIR evaluates and accumulates the impact on soil disturbance of each tillage pass within the farming system. It is based on operation tillage type, implement speed, tillage depth, and area disturbed. This rating reflects carbon loss, moisture depletion and fugitive dust emissions. A value of 200 indicates significant negative tillage impacts; 50–75 indicates less negative impact as from significantly reduced tillage; and below 30 indicates low impact such as with a no-till production system.

Figure 1 summarizes the results of the RUSLE2 runs. Because of localized sampling we need to emphasize that the RUSLE2 estimates are for comparison of changes in management only at a locality and are not to be extrapolated to or compared with results on whole watersheds or river basins where variables besides management affect average erosion rates and soil quality.

The figure shows a rather dramatic reduction in erosion with conservation tillage. Compared with rates in 1975 when most farming was by conventional tillage, erosion rates were reduced by half in 1990 on the sites in the high- and intermediate-precipitation zones when, it was estimated, reduced tillage was used on half or more of the land. Erosion rates were reduced by three-fourths on these sites when over half of the land on the high precipitation sites and virtually all in the intermediate zone were in some form of conservation tillage. In the low precipitation zone there was little change in rotations and/or farming methods between 1975 and 1990 but erosion rates were less by about a third in 1990 because of higher wheat yields and thus more crop residue for erosion control. Rates in 2005 were about half those in 1975 with about a fourth of the cropland in conservation tillage.

The reductions in soil erosion and changes in management practices after 1975 support the trends shown in Figure 1 for the SCI and STIR for the STEEP era. Based on changes in farm management, the SCI showed improvements of 40-plus to 60 percent by

High Precipitation Zone | Intermediate Precipitation Zone | Low Precipitation Zone

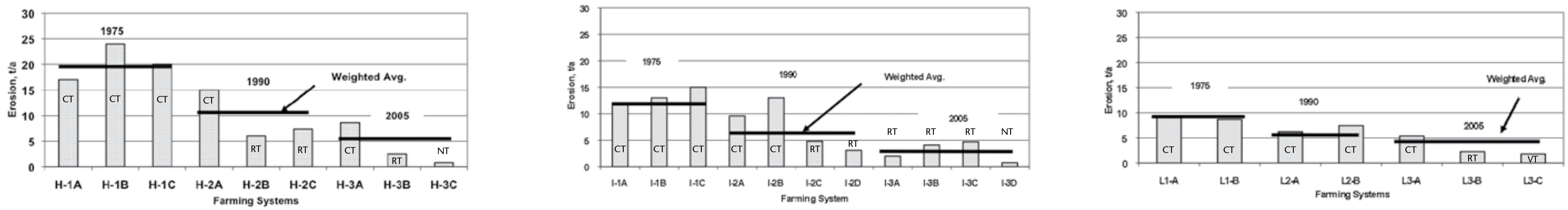

Figure 1-A: Average Annual Erosion

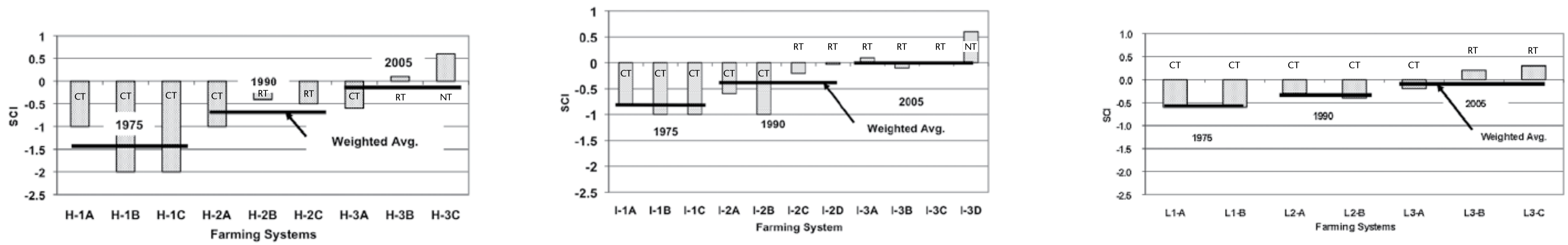

Figure 1-B: Average Annual SCI Values

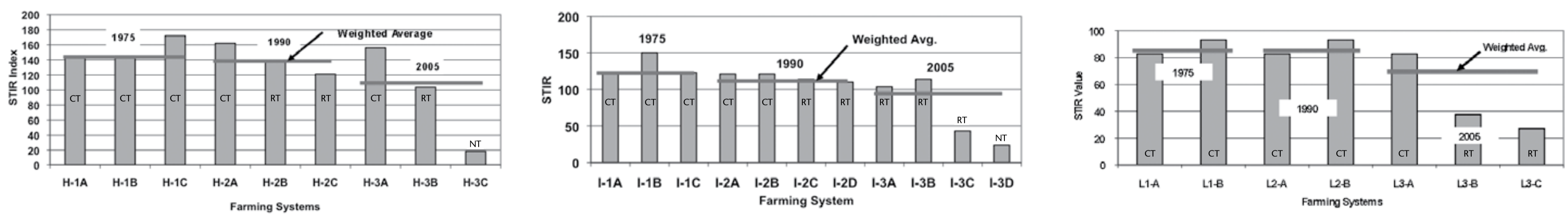

Figure 1-C: Average Annual STIR Values

Figure 1. Average annual soil erosion rates, Soil Conditioning Index (SCI) and Soil Tillage Intensity (STIR) and their weighted averages (horizontal bar) for typical farming systems during 1975, 1990, and 2005 in the high, intermediate and low precipitation zones. An erosion amount of 5 t/a/yr is considered tolerable for long-term, sustainable farming. An SCI of -1 is highly degrading to the organic matter, 0 is neutral gain/loss, and +1 is very beneficial to organic matter gain. A STIR of 200 indicates significant negative tillage impacts, 50–75 would be significantly reduced tillage, and below 30 a no-till production system. CT= Conventional tillage; RT = Reduced tillage; NT = No till. Refer to Table 1 for farming system (A, B, C….) details.

Table 1: Typical farming systems used during evaluation period for three precipitation zones.

Table 1-H. Typical farming systems and crop yields in 1975, 1990, and 2005 for the high precipitation sites.

Year	System[1]	Rotation[2]	Use %[3]	Yield per acre[4]	Tillage System[5]
1975	H-1A	WW-P-WW-P-WW-F	60	WW: 70 SB: 3 P: 2	CT: Plow WW residue (no burn). Surface tillages: 6 for P, 4 for WW. Includes deep chisel.
	H-1B	WW-P-WW-P-WW-F	20		CT: Burn and plow WW residue. Surface tillages: 6 for P, 4 for WW. No deep chisel.
	H-1C	WW-SB-P	20		CT: Burn and chisel WW residue, plow barley residue. Surface tillages: 6 for SB, 6 for P, 4 for WW. Includes deep chisel.
1990	H-2A	WW-SB-P-WW-SB-P-WW-SB-F	50	WW: 80 SB: 1.5 P: 1 SW: 50	CT: Plow WW residue (no burn), plow SB residue. Surface tillages: 6 for SB, 6 for P, 4 for WW. Includes deep chisel.
	H-2B	WW-SB-P	35		RT: Chisel WW residue, chisel SB residue. Surface tillages: 5 for SB, 6 for P, 4 for WW.
	H-2C	WW-SB-WW-SW	15		RT: Burn and chisel WW residue. Surface tillages: 5 for SB/SW, 4 for WW.
2005	H-3A	WW-SB-P-WW-SW-P	40	WW: 100 SB: 2 P: 1	CT. Plow WW residue, chisel SB/SW residue. Surface tillages: 4 for SB/SW, 5 for P, 4 for WW.
	H-3B	WW-SB-P-WW-SW-P	50		RT: Chisel WW residue, chisel SB/SW residue. Surface tillages: 3 for SB, 3 for P, 1 for WW (2-pass).
	H-3C	WW-SB-P-WW-SW-P	10		NT: Direct seed all crops with intervening sprays; no surface tillage.

[1] Indicates: Precipitation Zone (High, Intermediate, Low), Period (1,2,3), Farming System (A, B…)

[2] WW = winter wheat, P = pea, SB = spring barley, SW = spring wheat, L = lentil, F = tilled fallow, CF = chemical fallow (no-till).

[3] Percentage of acres in rotation by regional farmers

[4] Units of yield. WW and SW = bu/acre, SB, P, and L = tons/acre.

[5] CT = conventional tillage, RT = reduced tillage and NT = no till.

1990 and 80 to 100 percent by 2005 in the organic matter index, compared with 1975 values. These changes are an early indicator of a turn-around in the decline of soil organic matter that had long been associated with conventional farming. There was very little change in STIR values in any of the precipitation sites between 1975 and 1990 but improvements of a fifth to a third by 2005 compared with values in 1975. Overall, these indexes indicate credible improvements in soil quality brought about by increased application of conservation practices.

Supplemental Assessments

A study in 2005 sought to answer whether winter erosion had actually decreased since the early 1980s and if so, whether the causative factors were related to differences in climate or land management from previous times (McCool and Roe 2005). Findings were based on analysis of data sets of winter erosion obtained from monitoring sites within the Palouse River Basin during 1942–1982, and predictions with the Universal Soil Loss Equation (Ebbert and Roe 1998). Analysis of climatic records showed small differences in weather patterns between the two sets of years, 1940–1982 and 1983–2005, that slightly favored reduced erosion hazard from freeze-thaw effects and precipitation during the latter period. However, USDA progress records for 1979–1994 indicate increased use of conservation practices in 1994 compared with 1979, with a large reduction in estimated erosion in the Palouse River Basin (McCool and Roe 2005).

Table 1-I. Typical farming systems and crop yields in 1975, 1990, and 2005 for the intermediate precipitation sites.

Year	System[1]	Rotation[2]	Use %[3]	Yield per acre[4]	Tillage System[5]
1975	I-1A	WW-P-WW-F	80	WW: 55 P: 0.7	CT: WW residue plowed (not burned). Surface tillages: 4 for P, 4 for WW, 5 for F.
	I-1B	WW-P	10		CT: WW residue burned and plowed. Surface tillages: 4 for P, 4 for WW.
	I-1C	WW-P-WW-F	10		CT: WW residue burned and plowed. Surface tillages: 4 for P, 4 for WW, 5 for F.
1990	I-2A	WW-P-WW-F	20	WW: 70 P: 0.8 SW: 1.75	CT: WW residue plowed (not burned). Surface tillages: 4 for P, 4 for WW, 5 for F.
	I-2B	WW-P-WW-F	10		CT: WW residue burned and plowed. Surface tillages: 4 for P, 4 for WW, 5 for F.
	I-2C	WW-SB-F	50		RT: Chisel WW residue, chisel SB residue. Surface tillages: 3 for SB, 6 for F.
	I-2D	WW-SB-P	20		RT: Chisel WW residue, chisel SB residue. Surface tillages: 3 for SB, 3 for P, 1 for WW.
2005	I-3A	WW-SB-P	30	WW: 80 L: 0.55 P: 0.8 SB: 2	RT: Chisel WW residue, chisel SB residue. Surface tillages: 3 for SB, 2 for P/L, 1 for WW.
	I-3B	WW-SB-F	50		RT: Chisel WW residue, chisel SB residue. Surface tillages: 3 for SB, 6 for F.
	I-3C	WW-SB-CF	10		RT: Chisel WW residue. Surface tillages: 3 for SB, 1 for WW. Sprays: 3 for CF.
	I-3D	WW-SB-L-WW-SB-P	10		NT: Direct seed. Sprays: 1 for WW residue, 2 for SB residue, no spray or till for P/L residue.

Table 1-L. Typical farming systems and crop yields in 1975, 1990, and 2005 for the low precipitation sites.

Year	System[1]	Rotation[2]	Use %[3]	Yield per acre[4]	Tillage System[5]
1975	L-1A	WW-F	75	WW: 35	CT: Disk WW residue. Surface tillages: 6 for F.
	L-1B	WW-SB-F	25	WW: 40 SB: 1	CT: Disk WW residue; disk SB residue. Surface tillages: 3 for SB, 6 for F.
1990	L-2A	WW-F	75	WW: 50 SB: 1	CT: Disk WW residue. Surface tillages: 6 for F.
	L-2B	WW-SB-F	25		CT: Disk WW residue; disk SB residue. Surface tillages: 3 for SB, 6 for F.
2005	L-3A	WW-F	75	WW: 55 SB: 1.25	CT: Disk WW residue. Surface tillages: 6 for F.
	L-3B	WW-SB-F	15		RT: Sweep WW residue; disk SB residue. Surface tillages: 3 for SB, 1 for F. Sprays: 3 for F.
	L-3C	WW-F	10		RT: Delayed tillage, sweep WW residue. Surface tillages: 2 for F. Sprays: 2 for WW residue.

[1] Indicates: Precipitation Zone (High, Intermediate, Low), Period (1,2,3), Farming System (A, B…)

[2] WW = winter wheat, P = pea, SB = spring barley, SW = spring wheat, L = lentil, F = tilled fallow, CF = chemical fallow (no-till).

[3] Percentage of acres in rotation by regional farmers

[4] Units of yield. WW and SW = bu/acre, SB, P, and L = tons/acre.

[5] CT = conventional tillage, RT = reduced tillage and NT = no till.

In 1979 erosion control practices were being applied to about 0.4% of the 2,113,970 cropland acres in the Palouse River Basin. This increased to 21% in 1994 (Ebbert and Roe 1998). These practices were estimated to decrease erosion by about 1.7 million tons annually or about 10% compared with the late 1970s. Conservation tillage, including no-till, was estimated in use on 31% of the cropland in 1994 and accounted for nearly 70% of the reduction in erosion. Strip-cropping and divided slopes accounted for about 54% of the acreage under erosion control practices but only contributed to about 14% of the reduction in erosion whereas the 14% of the acreage in the USDA's Conservation Reserve Program contributed 16% of the reduction in erosion (Ebbert and Roe 1998).

Erosion affects soil productivity but also impacts water quality. It has been estimated that as soil is displaced from slopes by runoff, about a third is discharged as sediment into bodies of water where it becomes a major pollutant. Figure 2 by Ebbert and Roe (1998) with 10 years of data (1962–71) shows a clear relationship between suspended sediment yield in the Palouse River with estimated annual soil erosion in the Palouse River Basin which it drains. The authors suggest that, for Northwest conditions, it should be possible to infer trends in

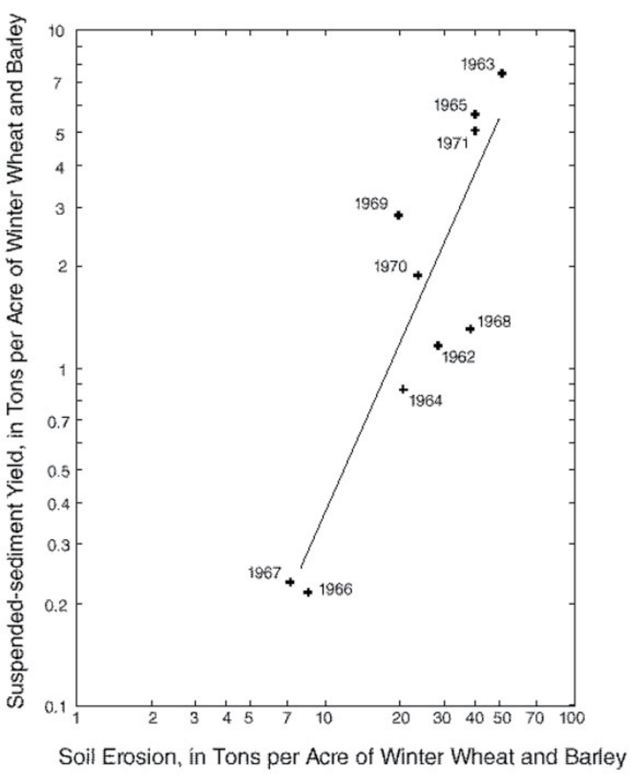

Figure 2: Soil erosion estimates correlated with suspended sediments yields from the Palouse River, 1962–71 (Ebbert and Roe 1998).

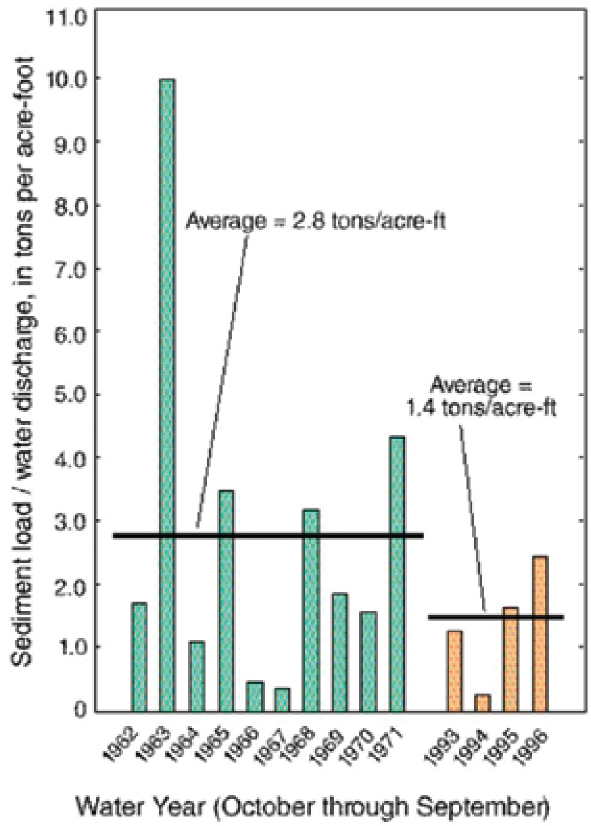

Figure 3. Comparison of historical record (1962–71) to the years (1993–96) from the Palouse River at Hooper, Washington, showing a decrease in the average annual concentration of suspended sediment (Ebbert and Roe 1998).

erosion from sediment transport during periods of storm runoff. Comparing the historical data with more recent measurements showed that the average sediment concentration in the Palouse River during 1993–96 was one-half the average for the years 1962–71 (Figure 3) (Ebbert and Roe 1998). This helps to confirm that recent erosion rates are lower than in earlier years and that the Palouse River is less polluted with sediment than before.

The authors duly note however, that concentrations of suspended sediment are highest during storms that produce large discharges. These conditions were more prevalent in 1962–73 compared with 1993–96 (Ebbert and Roe 1998).

Discussion and Conclusions

The widespread shift to conservation cropping systems and the estimated and observed reduction in soil erosion in Northwest wheat lands over the past two decades attest to the positive impact of STEEP accomplishments. These results are the culmination of research and education by a dedicated team of scientists and educators in collaboration with wheat growers and workers in the agricultural community who committed their time and talents to make the STEEP goals a reality.

The STEEP/IPM conservation system for the high precipitation zone utilized a diversified crop rotation, judicious weed management, and a mix of minimum tillage after high-residue cereals and no-till after lower-residue crops (e.g., pea). Its success is attributed to superior agronomic, economic and environmental results, compared with the highly erodible, intensive tillage system with limited rotation that it replaced. It is obvious that most of the individual STEEP accomplishments are integral components to the development of the conservation cropping system (item 3 under STEEP Accomplishments).

Similarly, development of the undercutter method from early STEEP research is now in the forefront, as a conservation winter wheat–fallow system that is presently being adopted by growers in the low precipitation zone. Large-scale use of the undercutter method has the potential to markedly reduce wind erosion and dust emissions without encumbering adverse agronomic and economic effects or hardship on the livelihood of wheat growers. Chemical fallow (no-till) or continuous no-till with spring cropping in the low precipitation zone, though having greater environmental advantages, are currently not options because of lower economic performance compared with the modified tillage–fallow conservation system.

The impact of STEEP is validated by the erosion/soil quality analysis, grower evaluations, and independent assessments of erosion and water quality. Growers unanimously confirmed from personal observations that erosion, particularly in the past decade, is considerably less than in earlier years. They also were convinced of substantial improvements of soil quality during that same time. Credit for these results was given to a large increase in the use of conservation practices in their respective localities. Similarly, the USDA progress records for 1979 and 1994 substantiate a 37% increase in acreage under erosion control over these years in the Palouse River Basin which is the heart of the Palouse region.

Although successful conservation farming systems have been identified through the STEEP effort for annual and fallow cropping, much remains to be done to modify and adapt these to local environments. Some can be accomplished with on-farm testing and by growers themselves but in other

One-pass direct seeded winter wheat into pea residue, 2005.

instances further research is needed. In the high precipitation zone, management of residues from high yielding wheat crops poses limitations with conservation farming, especially with no-till. Yields of subsequent crops are generally lower with high-surface-residue farming and there are difficulties with planting and weed control. Overcoming these may require improvements in implements and/or varietal modifications that control straw decomposition or grain/straw ratios. In the low precipitation zone, less tillage plus improvements in conserving surface residues should produce marked reductions in wind erosion and dust emissions with wheat-fallow farming.

The conservation provisions of the 1985 Farm Bill and modifications of others that followed was an asset to STEEP goals. On the other hand, STEEP research contributed to the design of conservation practices that enabled growers to achieve compliance without financial hardship. Other research enabled changes that allowed planting soil conserving crops without loss of base acreage of program crops. Currently with the aid of STEEP extension and education, growers are giving more attention to environmental and resource protection objectives. Though government programs have support for these activities in place, funding is too limited to have any widespread impacts. A case at point is the Conservation Security Program which funds worthwhile conservation objectives but on a too limited scale to achieve results across broad areas.

The federal investment in STEEP averaged about $0.5 M/yr over the duration of its life, i.e., 30 years to the experiment stations of the three states and the USDA's Agricultural Research Service. More was added by the state experiment stations for priority research and education but the amount is difficult to assess because of the array of projects that provided support for the STEEP effort. A rational judgment would be that STEEP operated on a total budget of approximately $1 M annually, or $30 M for 30 years. If one used a conservative estimate that the benefits of STEEP extended to 5 M acres, the investment cost is $6 per acre over 30 years, or 20 cents per acre annually. This is a trifle compared to what the program has accomplished in terms of saving and improving the quality of nonrenewable topsoil, improving water quality, and safeguarding the well-being of the farm economy in the Pacific Northwest. Moreover, its benefits extend far beyond the borders of the Palouse. These become incalculable where the advances in conservation farming from STEEP technology are applied to other regions to solve environmental, resource, and related economic problems.

Summary

Soil erosion has been a menace to Palouse wheat lands in Idaho, Oregon and Washington since farming began there in the 1880s. This region was identified by the USDA in 1980 as one of four having the most severe erosion in the US. Besides contributing to the loss of cropland productivity, the eroded soil was the primary pollutant in the region's bodies of water.

STEEP (Solutions to Environmental and Economic Problems) was organized in 1975 by the three Northwest Agricultural Experiment Stations and the USDA's Agricultural Research Service, with the mandate to develop and implement a conservation strategy that would halt erosion and its dire environmental consequences without economic penalty to the region's growers and related agricultural industry. The purpose of this assessment is to evaluate progress by STEEP over its 30 years of life in helping to achieve erosion control through conservation farming, i.e., did STEEP make a difference?

Direct seeded winter wheat into spring wheat residue, 2005.

Documentation for impact assessment was obtained from evaluation of STEEP accomplishments, interviews with growers in 2006, estimates of erosion by USDA-NRCS with the RUSLE2 prediction model, and review of related studies on erosion and conservation trends in the STEEP impact area. All sources indicate significant positive advances in conservation farming that led to major reductions in soil erosion during the past three decades.

Development of low-cost minimum till planting tools by STEEP scientists was the forerunner to the 2-pass seeding system for winter wheat adopted by most growers today. This practice requires minimal tillage and conserves crop residue on the surface for erosion control. This technology, utilized in combination with a diversified crop rotation along with judicious weed management, produced a conservation cropping system with superior agronomic, economic, and environmental results compared with traditional intensive tillage systems.

Most of the growers in the Palouse have now stopped using the highly erodible wheat–pea rotation with conventional tillage in lieu of the 3-year (wheat/barley/grain legume) rotation with no-till following grain legume and reduced tillage following high-residue cereals.

STEEP research has led to improvements in residue management, weed and disease control, and erosion prediction. Economic studies have informed growers of conservation benefits including eligibility for government programs as well as risks with aspects of conservation systems. STEEP research provided fundamentals for management practices to meet compliance provision of the 1985 Farm Bill linking eligibility for commodity payments with incentives for erosion and water quality control. It also provided rationale for amending the 1990 Farm Bill to include flexibility to grow crops that reduce erosion without penalizing base acreages of program crops. The award-winning STEEP extension and education program has been the mainstay of keeping growers informed about the latest developments of conservation research. Its on-farm testing program directly aided growers with implementation of new, economically-sound conservation technologies on their farms.

Interviews with growers confirmed that use of the moldboard plow and stubble burning has declined significantly, and reduced tillage has become standard on most farms. Most growers in the higher rainfall areas are now using the 3-year or longer conservation cropping systems as a consequence of STEEP research. They indicate that no-till is on the increase and predict that this trend is likely to continue. Wheat yields have increased over the past 30 years due to improved varieties and water conservation as a result of conservation farming. Growers note significant improvements in soil quality with no-till and reduced tillage in terms of tilth and organic matter accumulation. All of the interviewed growers claimed erosion had decreased significantly over the past 30 years but more so over the past decade as evidenced by lack of rills and gullies in fields and lack of sediment in road ditches and streams. Credit for reduction in erosion is given to STEEP for making conservation technology available to growers but also to government programs that favor implementation of conservation practices.

Calculations with the RUSLE2 water erosion prediction system for typical farm practices showed that estimated erosion rates decreased from an average of 20 t/ac/yr in 1975 to 5 t/ac/yr in 2005 on the high precipitation sites, and from 12 t/ac/yr in 1975 to 6 t/ac/yr in 2005 on the intermediate precipitation sites. They decreased from an average of 9 t/ac/yr in 1975 to about 4.5 t/ac/yr in 2005 on the low precipitation sites. Changes in soil quality indicators were positive and in line with the estimated decreases in erosion rates.

Independent assessments of the STEEP program help to confirm that use of conservation practices increased and erosion decreased in the Palouse since the 1970s. USDA progress records for 1979–1994 indicate increased use of conservation practices accounted for nearly 70% of the reduction in erosion annually by 1994 in the Palouse River Basin. Also, comparison of historical data with more recent measurements showed that the average sediment concentration in the Palouse River, which is the main drainage of the Palouse River Basin, during 1993–96 was one-half the average for the years 1962–71. Because there is a positive relationship between erosion and sediment concentration in the Palouse River, this helped to confirm that erosion rates in recent times are lower than in earlier years and that the Palouse River was less polluted with sediment than before.

The money invested in STEEP has been well spent in terms of return on the investment. Soil has been saved, water and air are becoming cleaner, and growers continue to fare well and improve on their stewardship of the land. With STEEP or a similar program in their midst, conservation farming will continue to develop and expand as growers adapt successful systems to meet the needs in their own production environments.

Acknowledgements

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A Note on Some History of STEEP and Future Outlook

The idea for STEEP was conceptualized in 1972 and motivated in part by the Water Pollution Control Act Amendments of 1972, enacted by the United States Congress in October of that year. The legislation was the first ever aimed at controlling pollution at the source, instead of after its release, as a way to achieve clean surface and subsurface water. It was realized that with conventional farming, Pacific Northwest grain agriculture would be impacted by the clean water rules because sediments from heavy erosion on its hilly farmlands were clearly a primary source of water pollution. Farming methods would need to be altered or drastically changed to reduce sediment discharges because law enforcement could subject individual growers to severe penalties for exceeding federal regulations on effluent levels. Changing farming practices without careful testing can be costly, thus, a major economic issue was at stake. In addition to environmental damage, conservation-minded growers, along with state and federal agencies responsible for soil conservation, were aware that erosion was insidiously reducing the production capability of once-rich farmland by wasting topsoil and leaving exposed subsoil and gullies.

Regional growers sought remedies through their state organizations on how they could protect land productivity and comply with new government regulations for limiting sediment concentrations in water bodies. Innovative leaders of the Washington Association of Wheat Growers (WAWG) along with scientists at the Washington State University Agricultural Research Center (ARC) and the USDA Agricultural Research Service (ARS) planted the first seed for STEEP. The outcome was an approach for designing a new type of wheat plant and management system that would hold the soil in place better than in the past and sustain economical productivity. At the request of WAWG President Elwood Brown in the fall of 1972, a committee organized by Dennis L. Oldenstadt, associate director of the ARC prepared a proposal calling for an interdisciplinary research effort on "New Wheat Plant Types and Management Systems for Erosion Control." It was submitted by WAWG for congressional funding as a special grant. This proposal was the basis for what eventually would become the STEEP program. It was not funded that first year and not until 1975 when the Idaho and Oregon wheat organizations supported the proposal as a tri-state effort. The first funds were made available to the USDA ARS in fiscal year 1975 and to the three states through USDA's Cooperative States Research Service in 1976. Thereafter, funding was available to the program on an annual basis.

Much credit for the implementation of STEEP and its continued existence lies with the foresight of the congressional delegations of Idaho, Oregon, and Washington when presented with the STEEP proposal in 1974. It was their thoughtful consideration of the future and hard work amidst numerous priorities that gave birth to STEEP over 30 years ago. The same holds for the tri-state senators and representatives along with their staff who worked with grower organizations and the universities to sustain it in the following years. Without the public support, STEEP would not have materialized which, in view of environmental restrictions and potential loss of natural resources, may have resulted in dire consequences for the Northwest farming community.

The first organizational and planning meeting of the STEEP program was held in Spokane, Washington, in the fall of 1976. It was chaired by R.J. Miller, director of the Idaho Agricultural Experiment Station and D.L. Oldenstadt, with about 25 scientists in attendance. The Oregon State Experiment Station and USDA/ARS were also represented. The individual reports and group discussions at the one day-and-a-half meeting focused on devising future research strategy with a multidisciplinary approach. R.I. Papendick, soil scientist and research leader with USDA/ARS at Pullman and E.L. Michalson, agricultural economist at the University of Idaho were assigned as co-chairs for managing STEEP and reporting activities and progress to the university and ARS directors.

The acronym STEEP, which stands for "Solutions to Environmental and Economic Problems," was coined by Dennis Oldenstadt in about 1974 and from then on became a household word to wheat agriculture in the Pacific Northwest states. STEEP is also well known to agricultural contacts in Washington, D.C., and collaborator associates nationally as a model program for unifying disciplines and policy in conducting regional conservation research and education across state boundaries.

Although the original program was designed around development of wheat plant types and their management for erosion control, emphasis from the combined states tend to weigh more heavily on soil and plant residue culture and economics in whole farming systems. Reduced tillage and no-till to minimize soil disturbance and keep cover on the land were, from the beginning, central to the STEEP approach for conservation farming. Only through an interdisciplinary effort was it possible to resolve problems with these highly effective erosion control practices

Originally STEEP was designed solely as a research program. After about five years it became apparent to many that there was limited dissemination of research findings, interpretation of results, and aid to growers with field application of new technology for conservation farming. It was simply not in the scientist's domain to conduct Extension and education work. It became common to hear "STEEP is one of the best kept secrets." Stakeholders brought to the attention of university administrators the need for a STEEP Extension and education add-on that would connect with the research effort. This was accomplished in 1982 with responsibility assigned to the existing Extension programs of the three universities. After several years it became evident that STEEP was an overload to ongoing Extension and education programs and thus, the decision was made to appoint a full-time person to this effort. In 1987 Roger Veseth was hired as Extension specialist for conservation tillage in a dual appointment with the University of Idaho and Washington State University. His primary duty was to disseminate research results from the STEEP program. Roger's tenure ended with his accidental death in 2003 and the position was filled next by Hans Kok who serves in this important capacity today.

(Continued on back cover)

What will be the future of STEEP? Some may rightfully say that the technological advances in conservation management have significantly reduced soil erosion in the high and low rainfall areas, therefore the work has been accomplished and the program is not needed anymore. The truth is that research and education programs like STEEP are needed more than ever because protecting the rural environment and land resources is an ongoing process if we are to keep our nation healthy and strong. Policy and priority changes, economics, social factors, and technology advances all bring about unpredictable forces and pressures on how our food-producing agricultural lands are used. With programs such as STEEP, where the returns are much greater than the costs, we have the assurance that our agriculture and its required resources will be protected from abuse and safeguarded for future generations.

Washington State University Extension

Pacific Northwest STEEP Solutions to Environmental and Economic Problems

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