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Global Perspectives... Local Knowledge

Agronomic Value Chains: Integrated Crop Management

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Value Chains

Value chains seem to about adding value to a product or outcome as it moves along from a user or consumer to the next user or consumer. Value is added at each step in the chain. Knowledge has value if it is incorporated into methods, products or combined to make new knowledge. In this sense, one can create a value chain from agronomic knowledge. If we are to prosper in an uncertain future, we can only do so if thinking is broadened in space and time. If we can mimic the diversity found in natural systems, and let variation flourish in our broadened thought processes, then perhaps, we can flourish in an agronomic value chain. We must not neglect any of our tools, technologies, systems or research areas. An agronomic value chain may include conservation agriculture linked to diverse cropping systems which is linked to the knowledge to grow a diverse crop … which builds the value chain. Stressing diversity in crop management systems is more challenging than stressing single tools. Using weed management as an example, 'quick fix' solutions seem imperative when faced with everyday problems. Responses from research and extension personnel have often stressed single tools as opposed to packages of tools in entire cropping systems. Building knowledge and integrating that knowledge into whole farm systems (Integrated Crop Management – ICM) builds security in problem-solving, consequently making the future a little less uncertain, business risk manageable, and consumer demands achievable.

Conservation Agriculture

The apparent success of production in meeting the increasing demand for food and fibre in the last 50 years depended on manipulation of capital held in the form of soil OM, nutrients, water and fossil fuels – ecosystem services. Natural systems provide goods and services that create and regenerate soil fertility, moderate regional climate, remove and restore carbon dioxide, minimize flooding, degrade plant litter and animal wastes and purify water. An unintended outcome of the intensification of agriculture is global degradation of soil and water resources, air quality, and the loss of biodiversity. Thus, the earth's agro-ecosystems have become increasingly stressed by economic/profit activities. Some scientists are currently trying to quantify the benefits of ecosystem services and the impact of agriculture practice on them to identify options that would lead to a more sustainable agriculture. The farmer is now being called upon to fulfill the conflicting roles of steward of the countryside and provider of food, while his or her activities come under increasing scrutiny. Questions have arisen as to the sustainability of our past success and the ability to meet the challenge of doubling production over the next 30-50 years.

The FAO has proposed the use of the term "Conservation Agriculture" as a generic terminology to replace the widespread use of "conservation tillage" to describe farmer's adoption of new tillage/seeding systems. The FAO rationale is that agricultural production technologies that are geared towards resource conservation involve more than tillage as seems to be implied by the use of "conservation tillage". They suggest that a definition for conservation agriculture as:

> Involving a process to maximize ground cover by retention of crop residues and to reduce tillage to the absolute minimum while exploiting the use of proper crop rotations and rational application of inputs (fertilizers and pesticides) to achieve a sustainable and profitable production strategy for a defined production system.

Given the importance of integrating residue management with crop rotation and production inputs, this FAO definition appears to best capture the systems approach that is critical to sustainable production systems. Crop residues alone do not make a sustainable production system, but rather can be seen as the mortar that holds the building blocks together. Any extensive farming system that does not include the retention of crop residues is unlikely to be sustainable.

Crop residues are critical for nutrient management, biodiversity, and soil and crop health in diversified cropping systems (Campbell et al., 1991; Lal et al., 1988; Lal, 1995; Liang et al., 2002; Lupwayi et al. 1998, 1999, 2001). The impacts of this crop residue addition include improved water infiltration, improved surface soil tilth, increased nutrient cycling and improved surface soil moisture retention, just to mention a few. Lal (1995) suggested that the ability of a soil to rebound from the process of degradation is influenced by both the amount of degradation and the restorative process. In fact, it is the balance between these two factors that influences the current and future productivity of soils. Crop residues are an important component of soil restorative management, and for the most part have a long-term positive impact on soil quality. In fact, crop residue carbon, in combination with nitrogen, is the biological 'driving variable' controlling soil organic matter accumulation. It is the management of this crop residue by the farmer that ultimately influences the rate of change in soil organic matter. Information on managing crop residues can be found on the RT Linkages website www.reducedtillage.ca

Diversified cropping systems

A diversified mix of crops is often considered a critical component of sustainable cropping systems. However, it has been suggested that sustainable agricultural systems must meet a number of criteria that increased diversification can help to achieve. A sustainable cropping system must incorporate several aspects: (a) productivity (maintaining or enhancing production), (b) security (by reducing the level of production risk), (c) protection (through the stewardship of natural resources), (d) viability (by ensuring long-term economic survival) and (e) acceptability (adoption of farming principles and practices which agree with the values within both the agricultural sector and society at large) (Blade et al., 2002).

Diversified cropping systems produce interactions between crops. In western Canada, the main crops are wheat, barley and canola, all grown as spring crops. The intensity of production is governed by the plant-available water, which can vary dramatically from year-to-year. Monoculture production is not a common practice, and research evaluating crop yields when grown on various pre-crop residues supports the idea of diverse crop rotation (Table 1). In general, the yield of a crop was lowest when seeded on its own stubble. Seeding broadleaf crops, like canola, flax and field pea, on cereal stubble was superior to seeding on broadleaf crop stubble. The reverse is also true. One reason for this relates to foliar diseases in a sub-humid environment, when similar crops are grown in succession. This may not be the situation in drier climates, or where cultivars with a high degree of disease tolerance are available.

Some monoculture production systems have proven themselves to be very effective in reducing yields through the accumulation of soil and plant pathogens (Cook, 1988), and the development of resistant weed and insect populations from repeated use of the same pesticides (Moss and Rubin, 1993). However, some of the highest crop yields recorded use a monoculture production system. For example, results of the US corn growing competition indicate that yields of 25,000 kg/ha have been achieved in a continuous corn production system, using intensive management practices (Murrell and Childs, 2000). Perhaps 'environmental' goals should be considered in conjunction with yield goals when evaluating a farming system.

TABLE 1. Yield response and variability of spring wheat, barley, canola, flax and field pea when grown on various crop residue types at Melfort, Saskatchewan, 1999-2001 (Johnston, unpublished data).

	Crop Residue Type					
Crop Grown	Variable	Wheat	Barley	Canola	Flax	Field Pea
		kg/ha				
Wheat	Yield	1601	2117	2004	1570	1874
	SE of mean	35	53	33	19	30
Barley	Yield	2440	1927	2587	2067	2337
	SE of mean	46	74	37	37	44
Canola	Yield	1305	1331	976	1039	1081
	SE of mean	41	32	27	20	24
Flax	Yield	952	1005	683	648	845
	SE of mean	18	11	20	9	25
Field Pea	Yield	2170	2016	1939	1634	1505
	SE of mean	23	49	35	37	24

The interaction among crops that has received the most attention is that associated with legumes grown in rotation. The impact of added organic matter with the incorporation of green manure, as well as the reduced immobilization of nitrogen (N) with decomposition of legume residues, has been demonstrated to have a positive effect on subsequent annual crop yields and quality in many parts of the world (Agboola and Fayemi, 1972; Brown, 1964; Campbell et al., 1990; Chen, 1993; Johnston et al., 1994; Miller et al., 2002). Legume crops can supply their own N when grown as a single crop (Clayton et al., 2004a; Clayton et al., 2004b), can supply N to non-legume crops with intercropping, and the residue left after cropping can supply N to following crops in rotation. The economic value, and importance to yield, of added N in the production of cereal grains makes legume crop production one of the cornerstones of any sustainable cropping system.

Diversity in the cropping mix on a farm can also minimize income variability due to heavy losses of the single crop in a monocrop system (Zentner et al., 2002). An unexpected pest infestation, or adverse climatic conditions, may significantly reduce single crop grain yields. Regions within western Canada with poor crop production potential, due either to marginal soils or short frost-free season have diversified agricultural production with livestock. With generally low incomes from grain farming, most farmers are anxious to minimize risks associated with a poor production year. This is also a common risk-aversion strategy among small farmers: a mixed crop-livestock system provides greater security than systems based on crop production alone.

Diversification can also be a necessary part of dealing with limitations on crop production inputs. Irrigation water supply is likely the most common example of this. Limited water is allocated either to the crops suited to the period during which the supply is present, or to those crops of highest value to the producer. As a result, a crop better suited to the dryland conditions would be selected in the absence of irrigation water.

Diversified cropping in the future will not only help meet production goals but also will reduce business risk, protect eco-system services and make crop management more acceptable for both the agricultural sector and society at large. Diversified cropping systems will continue to contribute to the development of whole systems that ensure the availability of all tools contributing to economic sustainability.

Where are the knowledge gaps? What are the research needs?

Pests in agro-ecosystems

Crop yield losses from pests can range from 0 to 100% in any particular area. However, in an average agricultural setting, crop yield losses due to pests probably range from 10 to 40%. Pests also cause losses other than yield, such as lower crop quality, more human labour, reduced equipment and fuel efficiency and lower market acceptance for agricultural products. In addition, areas put into production to compensate for pest losses (marginal land, rain forests, drained wetland and marshes, etc.) enforce costs on ecosystems and the environment. Pests limit the efficiency of management inputs such as nutrients supplied to crops and reductions in these efficiencies can also be responsible for environmental degradation.

Major plant disease epidemics, insect outbreaks and problem weed infestations are common occurrences in simple agro-ecosystems. These occurrences are rare in natural systems relative to cultivated systems because of inherent diversity in natural systems. In natural systems, few niches are available for any single species. In most agriculture systems, crops are grown as a single genetic type over vast areas.

Plant breeders, entomologists and pathologists have had tremendous success in developing resistance to limit epidemics and infestations however, there appears to be no relief from constantly adapting pest populations. Even when resistance is incorporated into new varieties it usually breaks down over time and new pest races are no longer susceptible to the simple resistance trait. By increasing the number of resistance genes that control a pest (multiple resistance), plant breeders have increased the durability of crop resistance to diseases and insects. Biotechnology techniques are available to easily combine many specific resistance genes into one genotype. Breeding programs continue to successfully incorporate new sources of resistance into plants, but have certainly not found solutions that will work indefinitely. Pest mutation, diversity and adaptation make this process a constant battle.

A knowledge gap exists on the interactive impact of crop management practices and weed, disease and insect pests. Pesticides dominate the tools used in pest management systems partly because researchers and industry have studied pesticides most extensively, and partly because pesticides offer simple and cost-effective, albeit short-term, solutions to difficult problems. The extensive and continued use of pesticides has led to ever-increasing cases of resistance to pesticides and ecosystem degradation. Blackshaw et al. (2000a) published an extremely important concept when they considered integrating cropping practices for weed management in a dry bean crop. Knowledge about cropping systems that encourage diversity of crops and pests is required before producers will replace the dominate pesticide tool with an integrated approach to pest management.

Nutrients in Agro-ecosystems

The benefits of inorganic nutrients in crop systems are well documented. Zero-tillage, N dynamics and fertilizer use efficiency have been well researched and contribute to an understanding of using nutrients under current crop production practices (Grant et al. 2001; Johnston et al. 1997, 2001; Lafond et al. 2001; Malhi et al. 2001; Soon et al. 2001; Soon and Clayton 2002). Fertilizer technology such as side-band placement, timing of application, and formulation have all contributed to the conservation technologies through efficient use of fertilizer, high yielding agriculture and synchronization of nutrient availability and uptake.

Crop production inputs, such as fertilizers, pesticides and irrigation water, contribute significantly to a crops cost of production. While all farmers are anxious to minimize their production costs, they also have the goal of maximizing farm productivity. The inefficient use of inputs is usually associated with either low input costs, high potential returns from production, or use of poorly combined agronomic practices. Application of fertilizers and manure, either greater than that used by the crop or inappropriate for the soil and/or climatic conditions, has resulted in contamination of surface and ground waters and very poor nutrient use efficiency.

Knowledge gaps exist in the relationship between fertility and residue management, the relationship between diverse crop residues and N cycling and the ability to predict nutrient supply, demand and efficiency throughout the crop growth cycle and beyond. Future challenges will include the interaction of nutrient management practices with soil, water, pests, weather and climate in diverse cropping systems.

Yield Goals

Maximum crop yield will vary depending on the genetic potential achievable in a healthy plant and the environment in which the plant is grown. Local knowledge of the environment is required to set realistic yield goals. It is neither biologically efficient nor sustainable to manage fields for yield goals significantly higher or significantly less than the attainable yield, given local environmental limitations (Cooke and Veseth, 1991).

A healthy crop not only yields more food, fibre and profit, it is also less likely to leave unused nitrates, which may leach through the soil profile and contribute to groundwater pollution. Where crop residues are left in the field, a healthy, high yielding crop also returns more OM to the soil than one with inadequate nutrients or pest management. A crop that yields well below what is attainable because of inadequate protection from pests and disease is also likely to use nutrients and water less efficiently, return a smaller profit and contribute fewer residues for erosion control and maintenance of soil OM. Perhaps maximum environmental “yield” will be considered in the future.

Fifty years of scientific progress and innovation in plant and animal breeding, irrigation, pest control, fertilizer technology, labour-saving technologies, and food processing have enabled food production to keep pace with the demands of a growing human population. To meet the demands of increasing populations, food production must double over the next 30 years. Innovation and technological breakthroughs must continue at the same, or a more rapid pace, to meet this demand. The challenge is to manage for attainable and affordable yield in a global economy/system that is becoming more uncertain as climate change and societal demands for sustainability increase.

Knowledge gaps become apparent as diverse crops are introduced into agro-ecological regions. Attainable yields are not well understood with current crops. Introducing crops to support diversified cropping systems without the agronomic knowledge to support an integrated crop management (ICM) approach is suspect if our goal is a sustainable system.

Beyond IPM – An Integrated Approach toward Sustainable Agriculture

Conservation Agriculture and diversified cropping systems will influence soil, air, water, nutrients, microbes, arthropods, and numerous other organisms. Attempts to manage natural resources, given the complexity of our ecosystem must include considerations for the entire system. In the past, our best efforts to improve Nature have usually foundered on some factor we failed to consider. Technology cannot be treated as an end in itself. We need to be careful not to justify technology because it is feasible, rather balancing its true risk-benefit for farmers, consumer and society.

Agricultural farming practices that systematically attempt to incorporate more biological processes and natural cycles into the farming system would improve the match between cropping patterns, production potential, and physical limitations of the land and climate. This approach would emphasize profitable, efficient production while conserving soil, water, energy, and biological resources. Combining knowledge of climate, soil, and agronomic principles can remedy short-term challenges and support long-term soil and crop health. Combining this knowledge with judicious use of inorganic and organic nutrients, pest management tools, and an understanding of attainable yields on each farm or region contributes to the needs of farmers and consumers.

IPM research should focus on combining several pest management tools into diverse cropping systems that focus on crop health (Dosdall et al., 2003; Turkington et al., 2000). For example, weed management is enhanced when competitive cultivars are augmented with higher seeding rates (Harker et al. 2003b) or farmers introduce operational diversity that may leave pests that are adapted to conventional systems "unprepared" to compete and thrive. More IPM research should focus on why pests are present rather than on their management (Buhler 1999). IPM requires less man-made inputs and more knowledge. It is clear that more knowledge of sustainable systems that include a diverse crop and conservation agriculture is required.

Successful crop production, regardless of the methods used, is a careful piecing together of numerous components into a system. IPM cannot be successfully implemented, and crop health cannot be achieved, if pest management is the exclusive focus of crop producers. Simply replacing one component with another is seldom successful. Focusing on crop competitiveness and health will lead producers to rely on packages of tools which include such things as sanitation, low disturbance seeding systems, higher seeding rates, narrow crop rows, optimum fertilizer placement, timely and efficient use of irrigation and diverse crop rotations. Crop competitiveness and higher seeding rates (O'Donovan et al. 2000, 2001a, 2001b) provide a form of biocontrol that uses agronomic principles or operational diversity (Clayton et al., 2004c; Clayton et al., 2004d; Harker et al., 2003a) to reduce pesticide use. Poor fertility can reduce crop health to the degree that all of the tools employed for pest management are negated (Blackshaw et al., 2000b). Similarly, good disease and insect management, in some situations, may be more important for weed management, because of their impact on crop health, than for their direct effects on crop yield. A healthy, competitive crop is the key in any cropping system.

A system-oriented strategy may be ecologically more compatible than component based technologies (Lal et al., 1988). Intensive agriculture has in some cases caused problems of environmental degradation and resource depletion. However, the science and technology supporting intensive agriculture has also been instrumental in the development of resource conserving agronomic practices. Conservation tillage, mulch farming, fertilizer placement technology, crop diversification and legume and cover crop management are just a few examples of the tools that have been developed to foster long-term sustainability of cropping systems. Only with the establishment and maintenance of long-term systems oriented research can the productivity, environmental sustainability and economic impact of cropping systems be evaluated. The need for the development of predictive tools and ecological and environmental indicators will be necessary to evaluate the value chain in these systems. Research on impact and adaptation of diverse cropping systems and ICM principles requires models to explore and minimize the impact of environmental change. Scientific challenges include improved agriculture ecosystems to increase yield, decrease reliance on pesticides and minimize inefficient use of all manmade and natural resources.

There are many barriers to widespread adoption of integrated crop management and diversified cropping systems by farmers. Extension workers can often help overcome some of the challenges with adoption by farmers. An innovative approach to scaling up research trials to the farm level, and involving the participation of farmers and extension advisors, is critical to adoption. Once the technology has been demonstrated and adapted to local conditions, the implementation of an outreach program becomes a necessity.

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