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Benefits of alfalfa in crop rotations

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Introduction Integrated crop-ruminant livestock (mixed) farming systems exist in many different forms around the world. Pasture leys or phases are common in humid and temperate zones. Conserved forages play a more important role in temperate zones where they are grown in rotation with grain crops. This paper describes some unique benefits of mixed systems over specialised systems and discusses current and future trends in crop-livestock integration.

Benefits of Crop-Livestock Integration over Specialisation Farming systems that integrate ruminant livestock and crops tend to be more sustainable because they provide opportunities for rotation diversity and perennality, nutrient recycling and greater energy efficiency.

Crop rotation diversity The benefits of forage legumes in rotation have been known for centuries. Sir John Lawes reported soil structural benefits of ley phases in the 1880's (Clarke and Poincelot, 1996). Benefits of forages for soil health (soil structure, nutrient status), salinity control, pest management, improved crop yield, and higher overall whole farm profitability are well-recognized (Entz et al., 2002).

Forage hay and pasture phases reduce weed and disease problems and increase productivity of following grain crops. In Canada, for example, alfalfa hay crops provide excellent control of several problem weeds including wild oat and Canada thistle (Ominski et al., 1999). In a survey of 250 western Canadian farmers, 83% of respondents indicated weed control benefits from forage phases for 3 years after forage crop termination while 71% of respondents indicated higher grain yields following forage than in annual crop rotations (Entz et al., 1995). Using 30 years of rotation trial data from Saskatchewan, Canada, Zentner and co-workers (in Campbell et al., 1990) demonstrated that integrated crop-forage rotations had a lower cost of production than annual grain production systems, and forage crops provided more income stability to grain farming than government crop insurance programs. In South Australia, pasture-grain systems provide relatively stable income even in drought years where grains result in large financial losses. When comprehensive economic analysis is carried out grain does not look nearly as attractive as a simple (and misleading) gross margin would suggest.

Perennality in the cropping system A striking example of what can happen when perennality is removed from the landscape is dryland salinity. In Southern Australia, alfalfa is being used to restore the hydrological balance and reduce the deep drainage that eventually results in dryland salinity (Angus, et al. 2001, Latta, et al. 2001). This restoration is based on alfalfa's deep root system and its ability to provide transpiration

leaf area for the entire year. Annual crops are unable to provide the necessary “perenniality” to better match plant water use to available rainfall .

Rising nitrate concentration in ground water has been partly attributed to the shift away from sod-based rotations. Deep-rooted perennials such as alfalfa (Campbell et al., 1994) and grasses (Entz et al., 2001a) are able to retrieve deep-leached nitrates better than annual crops, thereby reducing the nitrate contamination risk. The deep root systems of forages also enable carbon to be placed deep into the soil profile. Using a 38-year old crop rotation study in Uruguay, Gentile et al. (2004) showed that mixed farming systems (4 year pasture, 4 year grain crops) had significantly higher levels of subsoil C than crop only systems. Annual systems, even under grazing, return less organic matter back to soil than perennial pastures (Mapfumo et al., 2000).

Nutrient cycling Integrated crop-livestock systems allow opportunities for locally-controlled nutrient recycling. Nutrient cycling occurs by: 1) adding soil N by legumes; 2) excreta from grazing animals; 3) manure from confined fed animals; and 4) nutrient transfer specifically associated with livestock movement (i.e., nighttime corralling).

It is well-established that pastures, especially legume-based pastures, return a high proportion of nutrients back to the land (70 to 90%). Within grazing systems, the degree of nutrient recycling depends on pasture composition and grazing intensity with more intensive grazing increasing nutrient recycling to the soil system (Mapfumo et al., 2000). Removing forage from the land (i.e., hay and silage) removes nutrients and reduces rotational benefits of the pasture phase. For example, in a long-term (1920 to 1990) rotation study in NSW, Australia, Norton et al. (1995) reported that a change in red clover harvest management from grazing to haying contributed to a marked decline in yields of following crops, whereas in the grazed red clover, rotational crop yields were maintained. However, a long history of legume dominant pastures has resulted in many acidic soils in some of the most productive (medium-high rainfall) soils (McCown, 1996). Regular liming is the recommended practice to maintain a desirable soil pH. The problem becomes difficult to manage when the acidity progresses into the subsoil where liming is less effective.

Nutrient recycling opportunities are especially limited when conserved forage is transported and fed a long distance from its production site. Such separation of forage and livestock can reduce soil quality at forage production sites and accumulate manure nutrients at the livestock production site.

Energy efficiency Integrated crop-livestock systems have the potential to be more energy efficient than either specialised crop or specialised livestock production (Clarke and Poincelot, 1996). Even when ruminant livestock gain a high proportion of their nutrition from human usable sources (grains), their basal diet is typically comprised of human-unusable forage giving ruminants an advantage over pigs and chickens (Loomis and Connor, 1992).

A number of studies have confirmed that integrated systems use less energy per ha (Clarke and Poincelot, 1996) and have a higher energy efficiency than either specialised crop or livestock systems. In Germany, increasing off-farm feed purchases and decreasing reliance on grazing increased energy use in dairy production (from 5.9 GJ/ha to 19.1 GJ/ha) and decreased energy use efficiency (2.7 vs. 1.2 GJ/t of milk produced) (Haas et al., 2001). In Canada, integrated systems were found to have 10% higher energy use efficiency than specialized crop systems (Hoeppner, 2001).

Some examples of alfalfa in crop rotations

The Loess Plateau of western China On the Loess Plateau of Gansu, western China, local farming systems have evolved due to population pressure and soil sustainability issues. For example, soil erosion is a major constraint in the region, and mixed farms have replaced livestock grazing on sloping and terraced land. On the better flat land, intensive cropping has replaced mixed crop-livestock systems. Integration of crops and livestock in western China occur on both a local (on-farm) and area-wide basis (Figure 1).

Benefits of integrated crop-livestock systems over specialised production are well recognized in west China. Animals supply manures for soil fertility, draught power for tillage, and are important to generate cash flow, as opposed to grain production which is largely consumed for subsistence. Recent Government policies are aimed at increasing animal production. Other policies are aimed at replacing sloping cultivated crop land with either trees or perennial forages (cut & carry) to reduce erosion.

In areas where farmers have shifted production from mixed farming to specialised crop production, several risks have been identified. These include increased costs (chemicals and machinery), greater reliance on synthetic fertilisers over animal manures, the move away from largely organic systems to largely synthetic systems (risk of chemical residues, herbicide resistant weeds), and greater vulnerability to price variability in major crop commodities. Development of markets for livestock products would promote mixed systems.

Research is needed on integrating animal and crop production both on an individual farm-scale, and on a larger industrial scale. Local farming systems are complex, intensively managed, and productive on an area basis. However, the profitability and sustainability of current systems is poor and the integration of forage resources with cropping may provide solutions. Traditional Chinese farming systems have been highly integrated and there is opportunity for advancement through combining traditional knowledge and practice with newer technologies (GIS, computer simulation tools, etc.) for analyzing resource use efficiency.

Southern Australia The Southern Australian crop-livestock system is driven by the need to remain profitable in the face of declining terms of trade and threats to sustainability. Local population pressure is not a factor, if anything, declining rural population and reduced labour availability is an issue.

The southern Australia wheat-sheep farming system is constantly adapting to the prevailing market and biological constraints. Indeed, this high degree of flexibility is one of the appealing features of the system. Farmers continue to practice variations of this system precisely because it has proven resilient in the face of declining terms of trade and because it provides options for management of sustainability threats. Within the proposed model (Figure 1), the southern Australia farming system currently fits somewhere between the ‘mixed system’ and the ‘specialised crop system’. In South Australia there is an association between average annual rainfall and the relative emphasis put on livestock and grain enterprises. As rainfall decreases and grain yield declines and becomes less reliable, livestock becomes more attractive.

In response to declining profitability of wool throughout the 1990’s there has been an intensification of cropping at the expense of pastures and livestock in the medium to high rainfall zones, but not in the low-rainfall zone where reliable cropping options are not available. Since 2000, wool profitability has increased, and sheep meat has been profitable, resulting in an increase in livestock numbers and area under pasture. In addition, constraints to the sustainability of intensive cropping, such as herbicide resistant weeds and dryland salinity, have forced some growers to reintroduce pastures into their cropping systems. Pastures provide many options for non-selective herbicide management options and can provide a high water use option if a perennial such as alfalfa is used.

Australian researchers are making good use of analytical tools (eg., MIDAS, GrassGro and APSIM) to explore 1) grazing management options where annual and seasonal climate variability provides major challenges; and 2) analysing rotational sequences where knowledge of soil water and nitrogen is critical for managing integrated crop and livestock production under a variable climate. When used in conjunction with farmer knowledge, these tools can provide valuable insights into both the biology of the system, and farmer decision making processes.

Uruguay and Argentina Both Uruguay and Argentina have a long history of integrated crop-livestock production. Ley pasture systems (*festuca* and *lotus* spp.) are rotated with wheat, maize and other grains. A recent transition from integrated to specialised cropping (maize, soybeans under no-till management) has been most dramatic in the flat, productive soils in Buenos Aires province in central Argentina (Figure 1). In nearby southern Uruguay, where the land is hilly and susceptible to water erosion, mixed systems have been maintained as they have proven more sustainable than specialised cropping (Martino, pers. comm.).

Intensive cropping is driven largely by short-term profitability, sometimes at the expense of sustainability. An important question for Argentinian researchers is whether no-till grain cropping provides as many soil benefits as integrated grain-forage rotations. Subsoil constraints, such as compaction, may increase when deep-rooted perennial plants are absent in rotations (Martino, pers. comm.). Also, over-reliance on glyphosate, the herbicide that “supports” no-till cropping systems worldwide, is of concern. However, the

argument to retain mixed farming systems must be won on economic grounds. Comprehensive analysis including market and non-market values, and taking into account climate and market variability is needed.

Northern Interior Plains of North America Like Southern Australia, farms in western Canada and the northern USA are driven by the need to remain profitable in face of threats to sustainability and trade. Local population pressure is not a factor. Growing season length (frost-free days) is a constraint to plant growth. The dominant forage systems are perennial grass pastures and alfalfa or alfalfa/grass mixtures grown for conserved forage.

Traditionally, mixed farming has been practiced on poorer lands while specialised crop production is practiced in longer-season areas where soils are more productive (Figure 1). In response to strong wheat markets in the 1970's even traditional mixed farms abandoned livestock in favour of specialised grain production. Many of these farmers have switched back to integrated systems due to a prolonged period of low profitability and biological constraints in specialised cropping (e.g., herbicide resistant weeds, soil salinity). Currently, approximately 50% of farms in the region are integrated crop-livestock enterprises (Small and McCaughey, 1999) and many farmers have reinvested in infrastructure to support livestock in addition to crops. Despite having both livestock and crops in the same enterprise, the degree of integration is limited by management time, labour and producer knowledge. Integrated farming receives much less attention from researchers and extension workers than specialised production systems.

Organic agriculture in Industrialized countries Organic farming is creating a renewed interest in integrated farming in many parts of the world. The absence of synthetic chemical use means that pest management relies on crop rotation and soil fertility maintenance relies on crop rotation and animal manures. Over 30% of the landbase on Canadian organic farms is dedicated to forage crops (Entz et al., 2001b) compared with less than 10% in conventional production. Therefore, organic farming systems represent a shift from specialized to integrated production at the local farm level (Figure 1).

Organic agriculture is most developed in Europe. In Scandinavia, for example, close to 50% of dairy production is organically-managed. Fodder crops for these dairies, including seed crops, must be produced organically, creating new market opportunities for farmers and new challenges for researchers.

Summary and Conclusions

Crops and livestock will always be connected. The paper argues that the nature of this connection is important, as the interaction of crops and livestock has the potential to produce large benefits for people and the environment.

A trend observed in many countries was that mixed crop-livestock systems have largely been abandoned on better quality soils in favour of specialised cropping. We highlighted

a number of sustainability issues in specialized crop systems such as salinity, pests (including pest resistance), and soil health.

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