Pulse crops are being grown as an alternative during crop rotations with corn, wheat, canola, soy, and other grains and oilseeds. They have also become important to the North American diet as well as for export. Pulse crops provide good protein, dietary fiber, and phytochemicals, and Canada has been a major exporter of lentils in the past several years.

As a crop in rotation, pulses are used to break pest cycles common to monoculture, reduce the use of fertilizer nitrogen, and may improve marketing opportunities for growers. The area of pulse crops has increased in North America from just under a million acres in 1991 to nearly 7.5 million acres in 2006, primarily in the Northern Great Plains. Cropping systems have changed from crops followed by fallow in the semiarid Canadian Prairies and Northern Great Plains, where fallow was used to reduce the risk of crop failure resulting from soil moisture deficits. However, it has been found that fallow-based rotations reduce soil organic matter, primarily because less plant carbon is returned to the soil. Soils in southern Saskatchewan and the Palouse region of the U.S. Northwest lost about 50% of the original organic matter after more than 80 years of wheat-fallow cropping. After the advent of conservation tillage systems (minimum or zero tillage) in the 1970s, more soil moisture was conserved than under conventional tillage, and continuous cropping became a viable option for producers because soil moisture was conserved using the reduced-tillage regimes. As a result, fallow acreages in Canada and the United States began to decline.

With this decline in fallow phases, pest buildups began to occur, and other crops entered the rotations, as crop diversification was required. Pulse crops became attractive rotation crops, and their acreages increased. In the Canadian Prairies, field pea is a major crop, and lentil, chickpea, and dry bean are grown on significant but fewer acres. In the U.S. Northern Great Plains, dry bean and chickpea are the most common, but field pea and lentil are also grown.

Pulse crops affect soil biology

Pulse crops have a significant impact on soil biology, as they increase soil microbial activity even after harvest is complete. Along with nitrogen fixation, the rhizosphere activity of the crop increases plant nutrient uptake. Mycorrhizal activity enhances plant phosphorus and zinc uptake. Endophytic rhizobia enter the cells of nonlegume crops in rotation and influence nutrient uptake in nonlegumes. While pulse crop residues do have low nutrient content, microbes can decompose them more easily than cereals. Pulse crops influence nutrient cycling in soils by increasing microbial activity and nutrient content.

Because grain legumes are high-protein crops, they remove the vast majority of the nitrogen fixed in the harvested seed. The root and biomass that grow aboveground contribute to the effect on subsequent crops in the rotation. The effect of reduced nitrogen immobilization because of the low carbon/nitrogen ratio of pulse residues also helps improve nitrogen supply to following crops. While the yield response of growing a cereal on pulse residue would imply a greater nitrogen benefit relative to oilseed stubble, only a portion of this can be attributed to added nitrogen. It is not easy to estimate the nitrogen credit from pulse crop residue, and the range of estimated nitrogen supply from pulse crop seed yields indicates that nitrogen benefits cannot be related to shoot or grain yields. Fixation is the key to increasing pulse crop yield and to influencing the residual nitrogen left after a pulse crop is harvested.

Pulses and the environment

The use of pulses such as dry pea, lentil, dry bean, and chickpea has increased during the last 10 years in the Northern Great Plains, more than doubling to slightly less than 5 million acres seeded to pulse crops in 2005. Introducing pulse crops into predominantly cereal-based systems could potentially impact their overall greenhouse gas balance in several ways. Soil organic carbon levels on agricultural land in the Northern Great Plains are directly influenced by the amount of carbon returned to the soil in crop residue. Because the quantity and quality of pulse residues can vary compared with that of cereals, this factor can affect soil organic carbon levels.

Pulse crops have different pesticide and fertilizer requirements than cereals, and this is thought to influence the magnitude of carbon dioxide emitted from the fossil fuel use related to the manufacture and application of these inputs. The Intergovernmental Panel on Climate Change has proposed a standard methodology to prepare national inventories of greenhouse gas emissions. This approach assigns a nitrous oxide emission to the nitrogen in pulse residues that is returned to the soil and a second emission to the amount of nitrogen that is biologically fixed when a pulse crop is grown. Using default values from this methodology and assuming equivalent seed yields, the estimated nitrous oxide emission per unit area can be substantially higher from pulse crops compared with a fertilized cereal crop.

It seems clear that the concentration of carbon dioxide in the air has increased over time. But, while...
changing atmospheric carbon dioxide levels may impact crop growth, these differences are often minor relative to the impact of changing crop management practices (such as seeding date, fertilizer rate, and variety selection). The impact of changes in available soil water, shifting weed populations, and soil fertility changes can increase the challenge of adapting pulse crops in rotation. The genetic variability available to plant breeders to influence crop improvement will play a major role in pulse crop adaptation to climate change.

**Pulses and their adaptation to changing climate**

If pulses cannot change climate materially, the other question to be asked is whether, in the event of major climate change, pulses produce better than conventional grains, and if so, which pulses? In the November–December 2007 *Agronomy Journal*, authors of a report titled, “Adaptation of Pulse Crops to the Changing Climate of the Northern Great Plains,” reviewed agronomic requirements for soybean, dry pea, lentil, and chickpea. These crops are currently grown in different Great Plains locations, with soybean production concentrated in the southeastern region, including the subhumid regions of South and North Dakota. Dry pea, lentil, and chickpea production is mainly in the semiarid regions of the Northern Great Plains, especially in Canada. Dry bean is a warm-season crop similar to soybean, with expanded production in recent years. There is clear evidence that the climate of the Northern Great Plains has warmed, especially over the past 50 to 60 years and has had a significant impact on the rapid increase of pulse adoption to the Northern Plains.

Pulses are relatively easy to grow in the uncertain climate of the Great Plains. Because of this, the semiarid regions of Canada's prairies now extend the traditional wheat—fallow crop rotations. Pulses adapt well to no-till management, which make them even more adaptable to earlier planting. While the warmer early spring suggest greater use of the Great Plains and Canadian plains, it is easy to make inaccurate assessments of warming climates. Currently, it appears that spring plantings and other activities have moved to an earlier time since the 1960s, and that resulting blooming has shifted to about five days earlier each decade during the last 50 years.

Helping farmers adapt to climate change requires improving knowledge and skills, encouraging their adoption of new technologies, and expanding the array of options available to them. The authors of several papers have recommended that study be directed to the given uncertainties and serious consequences of potentially inaccurate assessments of climate change and the required adaptation strategies. They have cautioned that complacency is risky and advise vigorous effort toward understanding and preparing for potentially serious impacts on agriculture by developing adaptation strategies.

Pulse crops are categorized as cool-season (dry pea, lentil, and chickpea) and warm-season (common bean and soybean) crops based primarily on their ability to emerge in cool soil conditions and tolerance to frost. The lowest temperature appropriate for seed germination and crop growth is different for each pulse. Soybean needs a base temperature near 50°F compared with base temperatures near 32°F for chickpea, dry pea, and lentil. Soybean is planted between mid-May to early June in most locations in the Northern Great Plains to reduce the risk of frost injury. Chickpea, dry pea, and lentil tolerate a moderate degree of frost depending on cultivar, degree of acclimation, and plant stage. If frost kills the first shoot, axillary nodes below the soil surface generate new shoots. The resultant loss of plant vigor reduces yield potential but typically does not require reseeding of the field, although a late seeding date usually predicts a reduced yield potential. In a variety of studies, researchers concluded that seed yields of both chickpea and dry pea in a semiarid environment can be enhanced by promoting early seedling emergence, prolonged reproductive period, and increased pod fertility.

Pulses are generally fairly tolerant of low water content in soils, but this is different not only for different crops but for different varieties. In some cases, physical stress, such as drought, may be required to initiate seed set for currently available cultivars such as lentils ad chickpeas. It appears that the earth is growing dryer, so this should not pose a threat to additional cultivation of these pulses. However, along with an overall trend toward warmer and dryer conditions, changing climates are notorious for introducing wet weather in areas where it is unaccustomed, and this may be unwelcome.

Some farmers have used irrigation during the early growth cycle, especially when growing high-yielding genotypes, but the advantage depends on warmer, dryer weather seed set and filling. This hastens maturity and reduces the risk of fall frost injury, which may reduce seed yield and seed quality.

It appears that the daily minimum temperature has increased about 10% more than the maximum temperature. The increased length of the growing season is also apparent. This may cause farmers to rethink their patterns of sequenc- ing crops to provide the maximum yields, another reason why additional agronomic research is particularly helpful to farmers in this area.

Pulse crop development will depend, to a degree, on prediction of future climatic conditions and identification of crop traits that will allow the crop to respond well to the future climate. The anticipated longer growing season may allow use of longer times to maturity and greater yield potentials. Some researchers have suggested that the development of cold hardy plants could allow farmers to plant in the fall, increasing their ability to farm greater areas.

Pulses are becoming more important as they are recognized as healthy products with some special characteristics. According to some experts, 6 to 7 million acres will be grown this year, which will match the current canola industry in Canada and would surpass canola by 2015. Careful attention to weather models may make these crops still more
important, especially if research provides more useful characteristics to specific new varieties. What will these new varieties look like? We should see cultivars with increased resistance to foliar blight, winterseeding pulses that can avoid drought periods in summer, identification of cultivars with increased heat/water stress resistance, cultivars with higher yield response to increased carbon dioxide, and pulses that develop earlier to avoid late summer droughts. It will be important to keep an eye on the weather models and check their accuracy.