Intensive farming systems: efficiency and innovation for sustainability

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1. Introduction

North America consists of twenty-three countries of widely differing characteristics and it is meaningless to generalize about them. So just the two biggest countries by area, Canada and the United States of America (USA) will be discussed here when referring to "North America". It is appropriate because they are substantially different culturally and agriculturally from the remaining twenty-one. Of course, there are still differences which make generalizations difficult between Canada and the USA and also within them due to regional differences in practices, soil and field characteristics, social structures, and climate.

Canada and the USA are both developed countries with relatively high standards of living. The agriculture in these countries does vary considerably, but in general it can be considered as intensive agriculture except where the rainfall is low (without irrigation) or where the temperatures are too cold.

The traditional definition of intensive agriculture is where large amounts of labor and capital are used relative to land area. This is usually done to maximize production and economic returns. In contrast, extensive agriculture utilizes small amounts of labor and capital relative to the area being farmed. However, agriculture in North America has been able to function at a high level of productivity with small amounts of labor due to the benefits of advanced and appropriately-applied agricultural mechanization. So even though the amount of labor used is small, much of North American agriculture may be considered as intensive farming.

The plains in the center of the North American continent allow very large field sizes. Broadacre grain crops dominate with cattle grazing in regions with insufficient rainfall. Farm and field sizes are smaller near the coasts and in the eastern part of the continent where topography or crops requiring more labor dictate.

Canada and the USA produce enough to support their own populations (35 and 320 million respectively) and to export. This export production is a necessity since there will be a huge challenge to provide for all the world's inhabitants by 2050, especially populous Asia. The world now has over seven billion people. In the next thirty-five years about two billion more will join the world's population will grow by about 2 billion. On October 15th, the Global Harvest Initiative (GHI, 2014) released the 2014 Global Agricultural Productivity Report at the World Food Prize Symposium. They indicated that "global agricultural productivity is not accelerating fast enough to meet the expected agricultural demand by 2050". They indicated that the global rate of productivity growth is starting to stagnate.

Many suggest that agricultural production should double by 2050. Although the world's population will only increase by less than 30%, the doubling is required in order to reduce the existing malnutrition and to accommodate the changing diets of those with improving economies. This increase cannot be brought about only by increasing the land under cultivation. Most of the uncultivated land is unsuitable for productive and efficient agriculture. In fact, in many countries significant areas are being lost from agricultural production due to causes such as urbanization, erosion, salinization, subsidence, and contamination.

The ever-increasing demands for more food and other agricultural products must be met through increased productivity from the existing land. This has been happening in many of the high-income countries where there was sufficient capital available to make the proper mechanization and other investments to increase production. For example, GHI points to the increase in Total Factor

Productivity (TFP) as the ratio of agricultural outputs to inputs. **Figure 1** shows some data for the high-income countries.

2. Plant production agriculture in Canada and the USA

In Canada and the USA there have long been substantial, and often successful, efforts to maximize productivity and efficiency. This trend continues. As the Association of Equipment Manufacturers (AEM) points out, "Over the past century, agricultural production in the U.S. has increased by more than 500 percent, while the share of agricultural employment fell from 30 to less than 2 percent, freeing up labor to support growth. In the 1960s, one U.S. farmer supplied food for 25.8 persons. Today it is estimated a single U.S. farmer supplies food for 144 people in the U.S. and abroad." (AEM, 2014).

Contemporary agriculture in Canada and the USA greatly benefits from technological innovations which increase productivity and sustainability. Technologies such as precision agriculture, GMO's, drip irrigation, advanced pesticide chemistries, and no-till equipment have maximized production and minimized some environmental impacts.

Plant agriculture needs to produce food, feed, fiber, and fuel in ever-increasing amounts. The food is obviously needed to feed the increasing population and alleviating the hunger and malnutrition of some of the existing population. The task is complicated also by varying needs and the requiring of more than just caloric production, the caloric production typified by starchy foods such as grain and starchy root crops. Both improved health and consumer desires are demanding more fruits and vegetables and higher protein foods. This is a concern in both developing and developed countries, such as the USA and Canada where there is a big concern with obesity. For example, in the USA there has been an increased emphasis on "specialty crops" and the efforts to develop the technologies to increase production, reduce production costs, and improve quality of fruits and vegetables.

But plant agriculture is more than just food crops. The production of animal feed is very important, especially as the consumer desire for meats and other animal products, such as dairy and eggs, continues to increase. The consumption level of animal products in North America is already high and therefore requires much feed production. In addition, the export of feed and animal products from North America is also important. Increasing animal product consumption in Asia is one of the drivers.

Fiber and fuel needs also place demands upon North American plant agriculture. The fiber needs are primarily met by around five million of hectares of cotton produced in the southern part of the USA. Currently, the biofuels industry consumes large amounts of corn. Corn is the dominant feed grain in the USA. **Figure 2** shows the recent historical usage of corn in the USA and illustrates the use of corn for fuel has increased corn consumption.

The use of corn for biofuel ethanol has be controversial as some claim it diverts agricultural land from food and feed production. As cellulosic ethanol plants open, the market (the "blend wall") for gasoline blending becomes saturated, and enhanced petroleum recovery due to fracking lowers petroleum prices, it is expected that the use of corn for ethanol will not increase and may decrease.

3. Agricultural mechanization contributes to plant production in North America

From these great needs of plant production for food, feed, fiber, and fuel, it is apparent that intensive agriculture is needed to produce large quantities efficiently. But the cost of labor in North

America is high and agricultural labor supplies are limited. So advanced agricultural mechanization has been applied to achieve intensive agriculture over large areas.

Agricultural mechanization technologies are very important for plant agriculture productivity and efficiency. The advanced agricultural mechanization technologies not only allow the agricultural production tasks to be performed, but they actually increase the amount of acceptable agricultural products delivered to the consumer by causing better processes, better agriculture, and better timeliness. Contemporary agricultural machinery performs their process tasks better. For example, a modern grain harvester reduces harvesting losses and reduces grain damage, thereby harvesting more usable grain. Early agriculture machinery had to be designed to insure that it would work reliably, but contemporary agricultural machinery is designed more for the success of the plant agriculture. For example, a current planter will place a seed in a precise location and within a soil condition environment which promotes success. Precision agriculture is another example of better agriculture. The timeliness of agricultural operations has a big effect on agricultural production and quality. The high powers, operating widths, and speeds of the equipment now used in North America allows the operations to be performed when most of the crop is at its peak quantity and quality. In some situations the equipment capabilities also allow multiple cropping or more productive cultivars with longer maturities.

Although the farmers in North America have economic challenges, the high standard-of-living and the social-political support system, such as crop insurance, allow the farmers to take a long-term view. They generally want to maintain productivity and efficiency and hence sustainability is in their best interest. They try to maintain their soil and water resources for following years and can generally manage for long-term success, including buying the necessary equipment to promote that success. And they want to use costly inputs, such as seeds, fertilizer, and agricultural chemicals, in an efficient manner, thereby reducing the potential for excess to be released into the environment.

4. Innovation in North American agricultural mechanization

Innovation in North American agricultural mechanization is very high for a number of reasons. Perhaps the most important is that the local agricultural equipment manufacturing industry is well-established and generally located in agricultural areas where there is local inspiration. They have the financial resources and educated and experienced personnel to innovate. In addition, the highly competitive marketplace open to international competition requires them to innovate to maintain market share. The North American agricultural equipment industry is also supported by a strong component supplier base and other automotive industries with which it can share technological developments. The North American agricultural equipment industry also benefits from the developments and intellectual ecosystem of local firms and institutions innovating in electronics and computer technologies.

The diversity of climate, soil conditions, crops, and production systems in North America promotes a large amount of experimentation, by the farmers as well as the equipment producers. Because many farmers have well-equipped shops or access to good local rural facilities, they can experiment and innovate. And many of them do so. Canadian agriculture covers about 70 million hectares and the USA has over 160 million hectares of cropland and about 250 million hectares of grazing land. Even if technologies are developed which only are adopted on small fractions of the total farmland, there still are sufficient volumes of potential sales to justify development, marketing, and manufacturing investments in new innovations. In addition, there is support in every agricultural province or state from public sector institutions, such as Agriculture Canada, the U.S. Department of Agriculture, and land-grant and other universities to encourage innovation and promote technology transfer.

Given the diverse and huge agriculture in Canada and the USA and all the innovation that is ongoing in a dynamic agriculture, it is difficult to identify the dominant mechanization trends. But it seems that there definitely is a trend for a more complete and stronger integration of the agricultural system. This parallels the other forms of larger-scale integration in the developed economies and societies, as exemplified by the expansions of networks, “the cloud”, etc. This includes an integration in agricultural mechanization. For example, John Reid indicated that there appears to be a progression of the form “task—machine—machine systems—worksite—customer value chain—broader societal value chain” (Reid, 2014). This trend appears pretty obvious when examining the example of some agricultural machinery. Initially, there were automatic controls for individual tasks on agricultural machines. Then the controllers were networked together on a machine or a tractor-implement combination, as in ISO 11783 which is commonly known as ISOBUS (ISO, 2007). Now telematics is becoming popular. The technology is moving towards a point where there will be an integrated agricultural production system which can be managed and controlled to provide an overall system global optimization.

This integration is also reflected in the companies selling to farmers becoming integrated. For example, Monsanto has purchased Precision Planting Inc., and The Climate Corporation. And DuPont Pioneer is formally working with John Deere. This integration contrasts to what seems to be a trend of large North American corporations in other industries at this time to divest and concentrate on core businesses.

Another great technology interest in North America is in unmanned aerial vehicles (UAV’s), sometimes called “drones”. Even general public media frequently mention agriculture as a prime application area for drones. Given the spatial nature of crop production agriculture, remote sensing of fields and crops by aircraft and satellites has long been an object of much research and some application to production agriculture. But there are often issues, such as equipment costs, timeliness, data ownership, resolution, etc. As an alternative to aircraft and satellite remote sensing, some see drones are having a great potential application in agriculture. It is felt by them that small drones can provide farmer-controlled information when and where the farm operator requires it. For example, drones may be able to monitor a field to determine the extent and severity of a pest outbreak to provide input for a precision agriculture action. Being under control of the farm operator, the drone can quickly provide the needed information to that operator.

The successful commercialization in North America of advanced pesticide chemistries and GMO seeds which tolerate certain pesticides has greatly reduced the tillage requirements in crop production. But the increasing resistances of weeds to pesticides and the lack of new chemistries is causing concern. There is now more interest in mechanical weed control and further innovation is needed to develop technologies to perform intrarow weeding.

As mentioned above, it is anticipated that there will be a shift from corn-based ethanol to cellulosic ethanol. The change has not come nearly as fast as many expected, but there now seems to be some movement towards commercial implementation. The use of cellulosic biomass will demand significant advances in mechanization and machinery to efficiently perform the required planting, cultivation, harvesting, and transport activities of the biomass crops.

The advanced manufacturing technology of rapid prototyping, also known as 3D printing, is among the technology trends currently receiving the most publicity in the USA. The technologies for rapid prototyping of plastics are becoming ubiquitous in educational institutions and commercial firms. The ability to create a virtual solid model of a device on a computer and then have it immediately physically constructed is much appreciated by engineers and manufacturers. Rapid prototyping will help the manufacturers of agricultural equipment shorten their product development times and will improve the subsequent products. But it might also prove useful on the farm also because farms are often located great distances from suppliers of spare parts and other components. Large, remote farms may have their own rapid prototyping facilities in their shops to respond to breakdowns in a timely manner. To be most useful, rapid prototyping for agricultural machines will likely require machines which can handle metal alloys. While such machines are currently marketed and have been adopted by aerospace companies and others, they are currently not efficient and economic enough for agricultural equipment. But that may change.

Irrigation and efficient water use continues to be a problem. This is exacerbated when there is drought, such as there was in 2014 in the western and southwestern USA, and to a lesser extent western Canada. The continued movement towards computer-controlled and automated irrigation systems to make them able to respond to crop and soil needs promotes sustainability through more efficient water use and the protection of water resources. Water use is also made more efficient through the adoption of drip irrigation, microemitters, and other technologies which use less water while providing enough for the growing crop.

These and other innovations keep moving agriculture towards more productivity and efficiency. The continuously-improving agricultural equipment and improvements in its use through better farm management will increase production and sustainability.

5. Public responses to needs and innovations in agricultural mechanization

The various innovations and technologies discussed above are widely recognized and discussed. For example, one website intended for North American farmers lists the "most advanced agricultural technologies employed today" for farmers as (parenthetical comments mine):

- tractors on autopilot (automated guidance of tractors and other equipment);
- swath control and variable rate technology (precision agriculture application of inputs);
- your tractor is calling (telematics—communication to other equipment, farmers, etc.);
- your cow is calling too (tracking of individual animals);
- irrigate via smartphone (monitoring and controlling irrigation systems);
- sensing how your crop is feeling (optical crop sensing);
- field documentation (yield and other maps);
- biotechnology (breeding for pest, pesticide, drought, nutrient deficiency tolerance);
- don't forget to flush (manure handling and application control);
- ultrasounds and more for livestock (improved veterinary technologies);
- there's an app for that (applications on cell phones for management and control);
- smile for the camera (machine vision for machines, fields, and animals) (Farm Management, 2014)

The North American agricultural equipment industry similarly recognizes the needs and trends. In a presentation prepared for his fellow AEM staff (O'Brien, 2013), AEM Senior Vice-President Charlie O'Brien identified some of the challenges for today's North American farmers to feed our world as being:

- farm input costs;
- limited land and water resources;
- operations scattered or spread out;
- climate volatility;
- labor pool is less skilled and available;
- regulations and reporting;
- connecting stationary farm assets;
- mixed fleets;

- capital investments increasing;
- global market;
- more partners and service providers;
- uptime and continuous operation;
- keeping up with technology.

O'Brien proceeded to identify some of the current technologies and issues. Perhaps his slides might be approximately summarized to include:

- Precision agriculture and its component technologies (guidance, mapping, variable-rate, etc.).
- Agricultural automation and robotics.
- Drones.
- Telematics and machine-to-machine communications.
- Connected farm.
- Big data and data ownership.

There is concern within the agricultural and agricultural equipment communities about the near-term future because the commodity prices have fallen. **Figure 3** illustrates that for corn prices.

It is expected that low commodity prices will greatly decrease agricultural machinery sales. But as Figure 4 below shows, the retail sales of tractors and combines in Canada and the USA by unit numbers has held up despite the low commodity prices (AEM Reports, 2014). However, examining the data more closely, as **Table 1** (AEM Reports, 2014) indicates, there is a definite decline in sales of the larger, more expensive equipment which will affect the industry and the agricultural productivity growth.

It is obvious that there has been an impact of the low commodity prices which are expected to continue. But Charlie O'Brien (O'Brien, 2014) cautions against too much concern for reasons that might be summarized as:

- the underlying fundamentals are strong. An increasing population needs to eat;
- the farmers' debt-to-asset and debt-to-equity ratios are near post-1970 lows;
- the need for productivity gains to meet food demand are never-ending;
- there is limited new land available, productivity of existing land must be increased;
- innovation is driving the production of big data which must be handled by equipment.

It is interesting to observe the public sector's views and plans. The U.S. Department of Agriculture (USDA) has just released a strategic plan for the National Institute of Food and Agriculture. Under Goal 1 ("Catalyze exemplary and relevant research, education, and extension programs") it includes the following sub-goals:

- advance our Nation's ability to achieve global food security and fight hunger;
- advance the development and delivery of science for agricultural, forest, and range systems adapted to climate variability and to mitigate climate impacts;
- optimize the production of goods and services from working lands while protecting the Nation's natural resource base and environment;
- contribute to U.S. energy independence and enhance other agricultural systems through the development of regional systems for sustainable production of optimal biomass (forests and crops) for the production of bioenergy and value-added bio-based industrial products;
- combat childhood obesity by ensuring the availability of affordable, nutritious food and providing individuals and families science-based nutritional guidance;
- reduce the incidence of food-borne illness and provide a safer food supply;

- insure the development of human capital, communities, and a diverse workforce through research, education, extension and engagement programs in food and agricultural sciences to support a sustainable agriculture system. (USDA, 2014).

Global food security and sustainability are therefore important. Increasing and optimizing production while protecting the environment is a difficult goal to achieve, but appears to be a common goal of the private and public sectors in North America.

6. Summary and Conclusions

Given the size of North America and the diversity within it, it is difficult to establish generalizations. However, it might be concluded that:

- it is recognized that food, feed, fiber, and fuel production must be increased and performed in an economically, environmentally, and socially sustainable manner to meet the world's needs;
- North America will contribute with highly productive and efficient intensive agriculture through the effective use of intelligent mechanization;
- innovation in agricultural mechanization is ongoing in such areas as precision agriculture, robotics, integrated systems, and advanced manufacturing;
- the need for innovation and efficiency in continuing to advance a productive and sustainable agriculture is widely recognized in the private and public sectors.

References

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Figure 1: Growth in Agricultural Output of High-Income Countries *(source: GHI, 2014)*

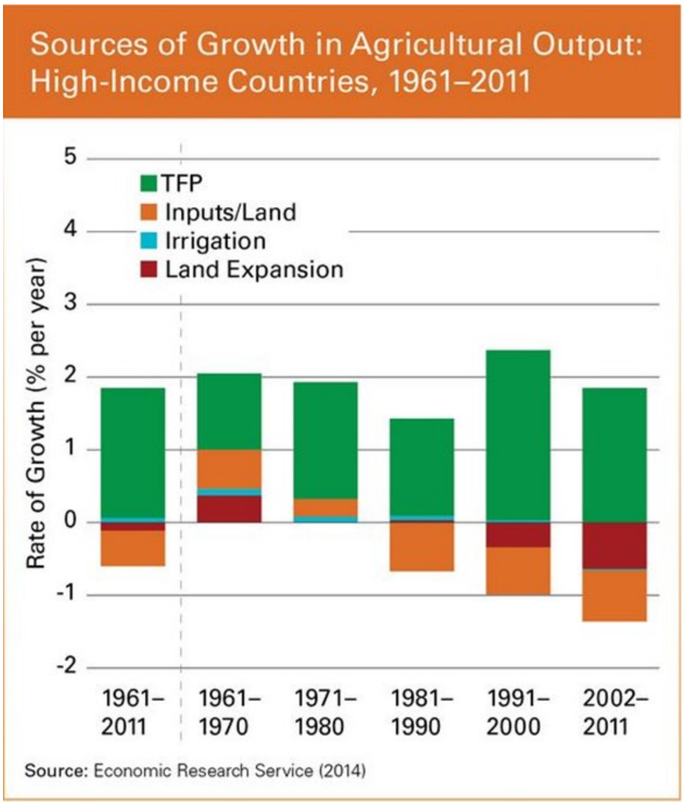


Figure 2: USA Domestic Corn Use *(source: USDA ERS, 2014)*

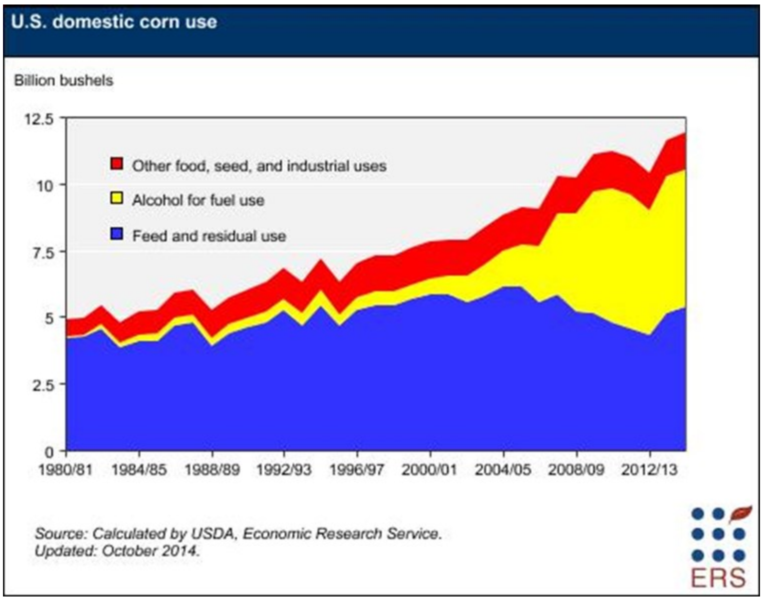


Figure 3: USA Corn Price

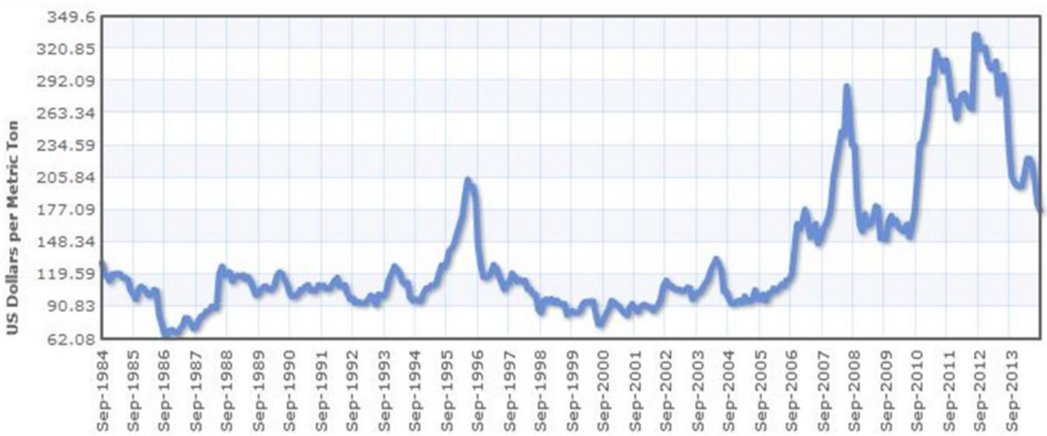
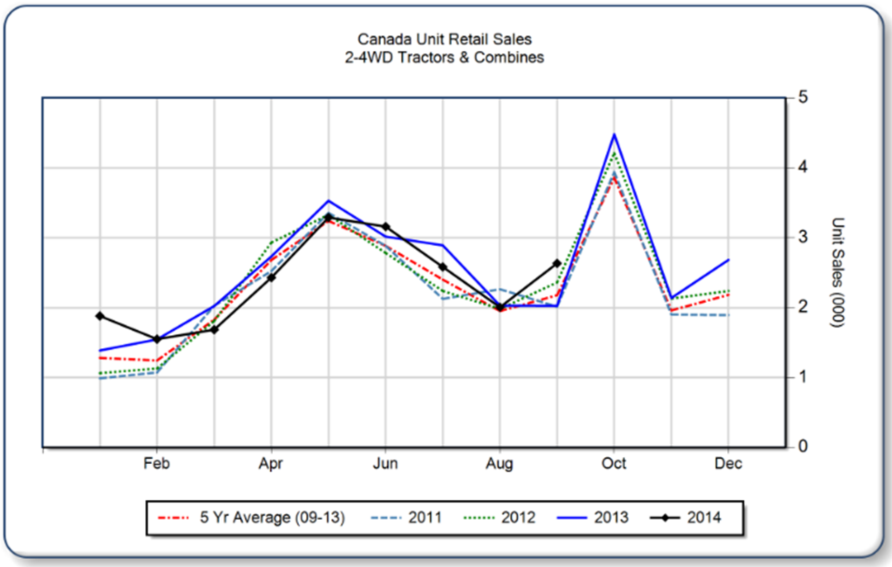


Figure 4: Canada and USA Tractor and Combine Sales *(source: AEM Reports, 2014)*



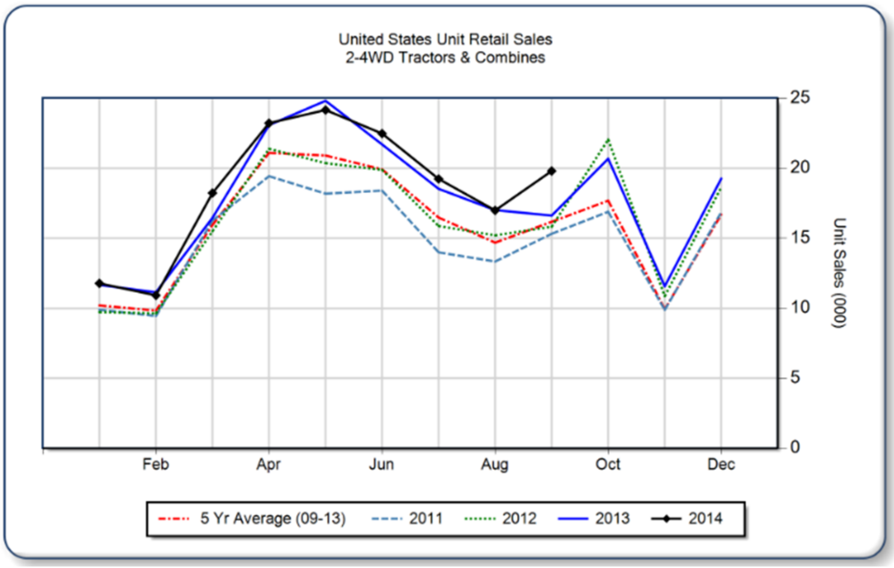


Table 1: September USA Tractor and Combine Sales *(source: AEM Reports, 2014)*

	September			YTD - September			Beginning Inventory
	2014	2013	%Chg	2014	2013	%Chg	Sep 2014
2WD Farm Tractors							
< 40 HP	10,100	7,697	31.2	88,058	81,044	8.7	55,789
40 < 100 HP	5,646	4,400	28.3	45,012	42,014	7.1	31,486
100+ HP	2,774	2,968	-6.5	23,442	25,649	-8.6	12,131
Total 2WD Farm Tractors	**18,520**	**15,065**	**22.9**	**156,512**	**148,707**	**5.2**	**99,406**
4WD Farm Tractors	**415**	**526**	**-21.1**	**3,926**	**4,630**	**-15.2**	**1,591**
Total Farm Tractors	**18,935**	**15,591**	**21.4**	**160,438**	**153,337**	**4.6**	**100,997**
Self-Prop Combines	**867**	**1,027**	**-15.6**	**6,375**	**7,688**	**-17.1**	**2,274**