Investing in Agriculture: Far-Reaching Challenge, Significant Opportunity

An Asset Management Perspective

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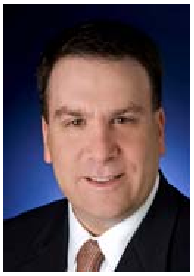

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"From an investor's perspective, the challenge of feeding and fueling the world is far-reaching, requiring sound governmental policies, education and training of practitioners, and the massive strategic deployment of capital."

The food for fuel debate reached a crescendo during the summer of 2008 as food prices soared to all time highs. As the financial crisis began to take hold of the global economy, energy prices sank and along with them, agricultural commodity prices. Many of the voices in the debate attributed the rise in food prices to the growing biofuels industry, while others pointed out the role of speculators and commodity funds. Once the bubble burst, the debate over producing fuel over food subsided, and food prices in some regions have come down. We point out in this paper that, rather than just a land shortage as culprit, the food "shortages" recently experienced globally were a result of sub-optimal agricultural policies, distortions including subsidies and export restrictions, a lack of investment, limited farmer knowledge and management, and productivity shortfalls.

It was true during the debate and still very relevant today that there is a growing imbalance of supply and demand of food (and fuel) that, in the long-term, will lead to higher food prices. As with energy prices, it is our view that the long-term uptrend in agricultural prices will resume and that the search for biofuel alternatives will re-emerge as an issue for debate. The good news is that this should stimulate investment.

Combining the food and potential fuel needs of 9 billion people, we project a 50% increase in productivity demand. Meeting this 50% increase is a great challenge. As a first stage, our research in collaboration with SAGE, of the University of Wisconsin shows that major increases in productivity by raising existing crop yields to the world's best management practices, are needed.

This challenge provides very large investment opportunities across the agribusiness complex including fertilizers, irrigation, mechanization as well as management practices and infrastructure development. However, these improvements are unlikely to be enough. More land, often marginal or degraded, so as to avoid deforestation, needs to be brought into production.

However, our research team points out both the constraints of water and carbon emissions that these agri-business solutions bring with them, as well as the continued uncertainty that just using existing well-known technologies and approaches will deliver sufficient production. Therefore the team explores further options including alternative approaches to agricultural practices such as bio-organics, radical shifts in land use and the development of biotech crops.

Further, our analysis shows that while even if enough land were available, there are a whole host of tariff systems and subsidies that create distortions on the global agriculture markets. Those distortions lead to a lack of capital formation around the logistics and the supply lines in the agricultural markets and also the development of farmland.

From an investor's perspective, the challenge of feeding and fueling the world is far-reaching, requiring sound governmental policies, education and training of practitioners, and the massive strategic deployment of capital.

Editorial Letter

Mark Fulton
Global Head of Climate Change Investment Research

“Even with a big influx of capital, feeding and fueling the world will challenge even the ability of the agri-business complex to deliver enough production in a carbon, land and water constrained world. New technologies and management practices are also on the table. ”

With global population set to rise to over 9 billion by 2050 and global incomes expected to increase, the agricultural sector faces great challenges to feed this growth. When the impact of climate change and greenhouse gas emissions is taken into account, this becomes even more of a pressing issue in a carbon constrained world. Furthermore, given agriculture’s large use of water, these forces challenge the management of the world’s resources: sustainable food, air and water for over 9 billion people. Agricultural production will need to undergo dramatic transformation encompassing both the development of systems for adaptation to climate change as well as integrating systems for mitigation of emissions. And the increasing demand for biofuels as transport fuel solutions will continue to be part of the debate.

What is emerging is a gap between demand and supply of agricultural production. This production gap can be met by increasing productivity (yield) and bringing more land into production (extensification). Meeting this challenge will require increased irrigation, mechanization and fertilization – and that will create more investment opportunities as well as the need for education and sound government policy. Rising prices of agricultural commodities will spur investment. However, irrigation uses water, fertilizer production creates greenhouse gases, and mechanization can increase emissions. What is required is highly sophisticated land management with precision irrigation and fertilization methods. On top of this, more marginal and degraded land will have to be brought into use. Hence, we are looking for a dramatic improvement in the productivity of farming inputs.

To feed and fuel 9 billion people, subject to the above mentioned constraints, farmers, markets and governments will look at a whole host of options. Alternative approaches are being researched and tested in development such as the re-emergence of small, self-sufficient organic farms, characterized as, local, multi-crop, energy and water efficient, low-carbon, socially just, and self-sustaining. Alternatively, a massive re-allocation of land-uses in order to produce agricultural goods from the most optimal regions on earth based on climate, soil and water constraints has been proposed, without regard to existing infrastructure. While a complete overhaul of how land is used on a global basis would be hard to implement in the short-run, long-term planners of agricultural development need to consider the carbon-water balance in their efforts to increase agricultural productivity. The question here for both scenarios is scalability and implementation.

Furthermore, the use of biotech crops will continue to be pursued by industry, government and investors. While the challenges in developing biotech crops require substantial research and development, and a robust regulatory environment, they offer great potential to substantially reduce water and fertilizer inputs, and increase productivity. We acknowledge the sensitivity of this issue and the accompanying complex ethical and social equity issues. And while this remains controversial and often seems to mirror the debate in power markets around nuclear energy – namely the safety issue, we believe that farmers, markets and governments in many regions faced with the enormity of the agricultural challenge will look at all available options including safe biotechnologies in crop science. On top of all of this, policy makers and scientists are increasingly asking how agriculture can help to mitigate carbon emissions. Sustainable forestry; addressing deforestation, and ending slash-and-burn agricultural conversion are obvious answers. Carbon sinks can also be created through practices that sequester carbon in agricultural soils, such as low tillage and biochar, but these are highly complex and only outlined in this paper.

We therefore recognize that finding a solution that can feed and help fuel 9 billion people in a sustainable and economically viable way, in a constrained world, will require huge investments.

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Executive Summary

The growing global population, with its increasing need for energy and food, presents a challenge for the planet: How can the ever-increasing demand for these resources be met in a sustainable manner? This is of particular importance in light of climate change: Emissions of greenhouse gases from energy and food production causes climate change. More people means more demand for energy and food production, and more demand for production means more carbon emissions.

The focus of this paper is on how we can try to meet this challenge of boosting agricultural productivity to meet the needs of the Earth's ever hungrier population. The paper looks at this challenge through 2050, and presents as-of-yet unpublished data from agricultural models.

The changing patterns of climate can potentially have severe impacts on agricultural productivity both ecologically as well as economically. Due to shifting precipitation patterns, movement of insect populations, more dramatic shifts in daily temperature regimes, and other large scale ecological changes that come with climate change, agriculture will most likely be severely impacted by climate change. The move to increase production for biofuels to reduce transport emissions is a further feedback loop linking agriculture to climate change. Skillfully managing this interaction between agriculture and climate change is a grand challenge.

Our conclusion is that it is going to be hard to meet the challenge and all available technologies will be looked at and massive investment will be required.

Meeting the Demand for Agricultural Production

Growing demand for food and fuel have been implicated as the cause of the wild fluctuations in food prices, which has been the focus of public and government attention over the past year. The fundamental drivers of the trend of increasing demand are growing population and GDP. GDP growth, in particular, has supported diets richer in animal protein and calories overall (FAO 2008, USDA, 2008). In addition, government biofuels mandates have diverted some agricultural production to biofuels. Due to the "perfect storm" of increasing food and fuel demands over the past several years, and the high visibility of the climate crisis, a food-versus-fuel debate erupted last year, even though globally only ~4% of grain and oil seed were used for biofuels in 2007 (but as high as 30% in the US for maize).

Long-term, the forecasted growth in demand for agricultural products will require supply-side forces to boost agricultural output and to accommodate both increased food demand and biofuels mandates. The environmental implications of cultivating increased 1st generation biofuels feedstocks (i.e. food crops) also open the door for research and investment in cellulosic, algae and other emerging technologies. This is just one illustration of how the entire agricultural complex requires significant investment even in difficult times.

Agricultural lands have also been suggested as potential sinks for carbon sequestration. As the climate change debate heats up, the need to reduce atmospheric greenhouse gases becomes ever more acute. The potential to use these lands to offset and sequester greenhouse gas emissions from other sectors has highlighted the need for improved management of our soils and forests, and underscores the need for spatially explicit planning of agricultural development.

Recent market trends and what they mean for the future

Most recently, in 2008, the agriculture sector was tremendously volatile due to correlation of the sector to oil, a weakening US dollar and some biofuel-driven demand for corn. However, since then commodity prices have corrected, but it is our view that long-term agricultural demand may result in a resumption of an uptrend in agricultural prices inline with demographic trends.

Massive investment in agribusiness is required if we are to be capable of feeding the world over the next half-century, while providing an increased volume of biofuels. This will require a significant increase in both the yield of many crops in many parts of the world driven by irrigation, fertilization, mechanization. Additionally, the use of degraded and abandoned agricultural lands will be necessary, particularly for biofuel production, which should be dominated by sustainable feedstocks. Care must be taken to provide land use intensification, rather than solely land use expansion. Sound government policy, broad scale farmer education and private capital are needed.

Land-Use Analysis: Measuring the Production and Yield Gap by Major Crop and Region

In this study, we present an analysis that seeks to understand local trends in order to raise agricultural productivity and meet global shifts in demand. We consider the geographic location of agricultural production and lay out a framework for assessing potential production increases. With this analysis, we determine where we can expect to raise productivity through irrigation, fertilization, use of biotech crops, increasing cropping intensity and selecting areas for growth of biofuels that do not compete with food production. Furthermore, we outline some growing opportunities in the agribusiness sector that can lead to improved efficiency, enhanced productivity, and minimal environmental damage. The analysis spans from the global macro level to the crop by crop, region by region level.

Using analytical maps derived from geographic information systems (GIS), it is possible to determine how much land area is currently under pasture, used for food production for humans, utilized in feed production for animals and used for biofuels production. For the major representative crops tracked by the Food and Agriculture Organization (FAO), our current demand and production estimates show sub-optimal production in our agricultural system, as it exists today. In order to close the gap between business-as-usual production and rapidly increasing demand, we essentially need to double current production.

Production can be raised in 2 ways; by increasing yield and by increasing cultivated area. In terms of improvements to yields, some regions have much lower yields of the same crop than other regions with similar climates (Licker et al., submitted). This difference, or “yield gap", can be calculated for each kind of climate in order to quantify the difference between the higher producing regions and the lower producing regions. Comparing current production with the 90th percentile production level for a given crop in a given type of climate, shows where agricultural systems can increase production.

Constraints for Raising Productivity

There are several constraints to raising agricultural productivity. Environmental damage arising from misuses of chemical fertilizers, irrigation and machinery include land degradation and irreversible ecosystem losses of biological and genetic diversity. While irrigation can help improve productivity, it may become physically infeasible or highly regulated in water stressed zones. Social issues such as ill-defined property rights and urbanization limit the potential for sustainable agricultural expansion. Moreover, poor infrastructure and limited farmer education also hinder productivity increases. And finally, while we do not explicitly forecast food or land prices in this analysis, clearly higher prices, while painful in the short-term, provide the stimulus for investment and the supply side response.

Investment Implications

Supply Side Response: Closing the production Gap by raising yields and using more land.

We view the emerging production gap between demand and supply as having two potential solutions: 1) raise productivity (closing the yield gap) and 2) bringing on additional land into production. The major industry trends expected to drive agricultural productivity growth over the coming decades include greater irrigation, increased nitrogen fertilizer utilization, and higher yields for crops. Each area has seen increasing activity in technological development over the past ten years, as evidenced by the research and development of many multi-national agri-businesses and the increase in patent filing and publication worldwide. While there has been investment in the agricultural sector over the past few decades, mostly in Europe and the US, it has only had marginal impact on agricultural growth on a global scale. Much of the worlds’ subsistence farmers have not seen much investment into their agriculture sectors. With proper deployment of capital, technology, management, and education, growth in productivity can be increased. Commercializing agricultural production across the globe will require tremendous investment in the sectors listed below.

1**. Irrigation** remains a key input for raising productivity across a broad range of lands. A GIS system helps us discover areas where irrigation has improved yields and identifies areas for further improvement (e.g. deployment of more efficient irrigation systems).

2. **Fertilizer** – optimizing application rates provides an opportunity to raise productivity. Analytical maps show us where fertilization is improving yields, and the geographic patterns of application. By improving the efficiency of applied fertilizer and water, the potential associated water quality problems and emissions of nitrous oxide could be decreased.

3. **Agricultural equipment** now includes high-performance spraying, harvesting and construction equipment, as well as smaller tractors and upgraded utility vehicles. Precision farming products that optimize efficiency in farming operations are becoming more prevalent in developed economies. They include integrated machines with advanced guidance systems, display options, and comprehensive information management.

4. **Farm commercialization** using sophisticated management, technologies, and inputs results in greater and more consistent output, and has the potential to raise agricultural productivity across the globe. For this to occur, significant investment must be made into the infrastructure of an agriculturally productive region. Spatial information can help policy makers in identifying where infrastructure development investments should be placed in order to integrate farms at all production levels. The large-scale financing required can be insured using agricultural risk management solutions in meteorologically challenging areas to permit the investment required to increase crop production significantly. Additionally, attention must be paid to raising the competence levels of farmers in adopting and using these technologies and management practices. This area of investment is typically under the responsibility of the state or national extension services. We believe that this is a strong area of investment opportunity for private capital as well.

5. **Leading companies in supply chain management** between developing countries and emerging economies capitalize on the dismantling of inefficient and bureaucratic agricultural systems and putting into place transparent financial and efficient logistics networks.

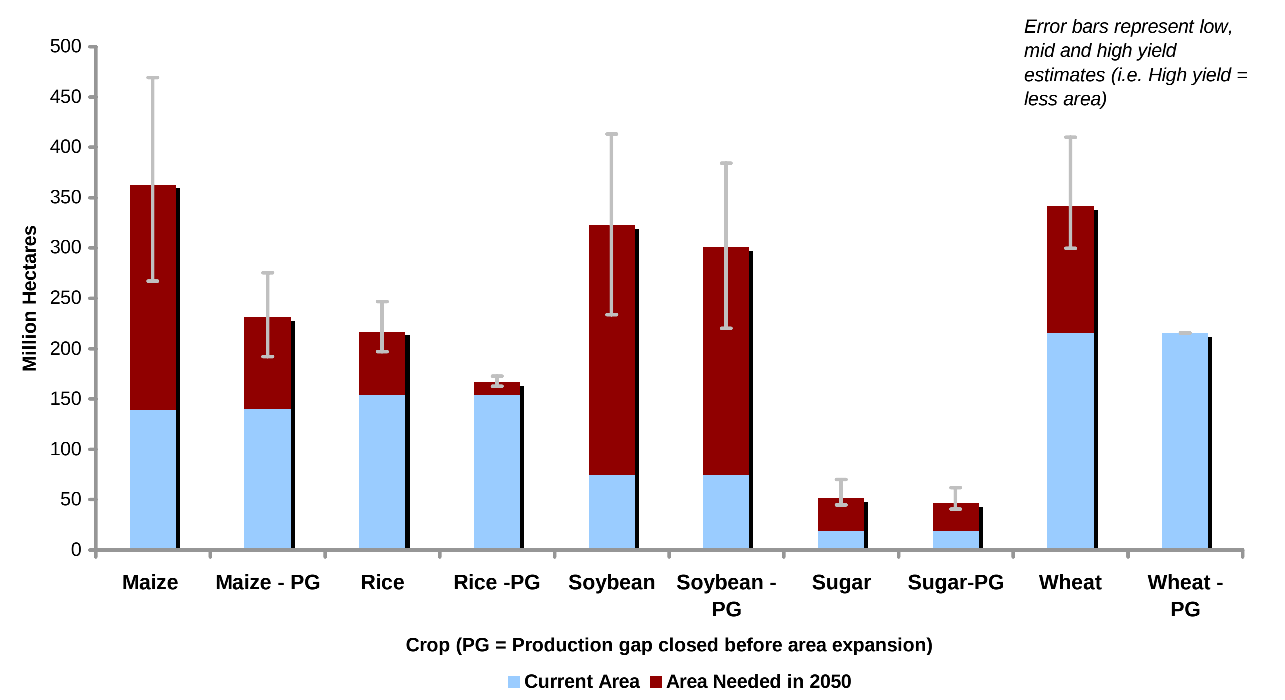
6. **Land Supply Response-**

Intensification: Raising the productivity of existing croplands through technology developments as listed above will help close the production gap. Using the spatial analysis tools as described will help identify where the production gaps can exist and are most likely to be closed.

Extensification: In order to meet the growing production needs beyond the improvements of productivity, additional land must be brought into production (Exhibit 1). Many land use types that currently exist have the potential to provide incremental production growth without expanding into forested land. They include; multiple cropping on exiting lands, improving degraded crop and pasture lands, bringing non-forested abandoned croplands into production and converting productive pastures into biofuel production.

Biofuels, a Special Case: Current feedstocks of 1st generation biofuels (e.g. corn, soy, sugar cane) compete with land needed for current and future food production. Generally, it is our view that while sugar cane is likely to remain viable, other agrofuels will not be seen as acceptable for biofuels and new feed stocks used in second generation technologies, such as ligno-cellulose and algae are developed and commercialized. If we are both to feed a growing, more affluent population and to use alternatives to fossil fuels, innovation and collaboration is needed across many industry sectors. Even though biofuels remain a small percentage of overall fuel consumption, as consumption increases, techniques that can be used to provide substitute feedstocks for second-generation biofuels that do not compete with current or future land will be required. Additionally, degraded croplands and pastures, rehabilitated non-forested abandoned croplands, and multi-cropping on productive lands will also be essential.

EX 1: Area needed to meet demand for major commodities in 2050



Source: DBCCA analysis, 2009.

Biotech and Genetically Modified Organisms (GMO) Crop Options

Even with the deployment of all the factors listed above, it is by no means sure that the world will get its crops to best practice levels or find enough degraded land in time. At the same time, water is becoming increasingly stressed and fertilizers currently emit greenhouse gases. In this context, many farmers, markets and governments have looked at the potential for biotech, or in some case Genetically Modified Organisms (GMO) or biotech crops, that can increase yield with lower water and fertilizer inputs. As investors, it seems to us that some regions of the world will, similar to the case with nuclear energy among renewables, look at developing this sector within a robust regulatory framework.

Policies

While the field of agricultural policy development is deep and complex and beyond the scope of this report, as investors, we need to recognize how policies influence agri-businesses. The primary goals of any agricultural policy are to protect food security and promote economic development. Policies that promote global free trade will do more to raise productivity and thereby promote agricultural and economic development in emerging economies in the long-run. The global food system should be a free and fair trade system that fosters growing the right crop on the right soil, in the right climate, with the right technology and management practices, as depicted in our analysis. Policies such as Renewable Fuel Standards, which encourage "second generation" biofuel mandates, development of infrastructure such as transport, ports, telecommunications, energy and irrigation facilities, fostering management skills, labor supply and capacity to use modern technology (e.g. global positioning systems) will all help raise productivity.

Conclusion

In the face of growing population, increasing prosperity, and climate change, the global agricultural system must modernize and fully integrate the production of food, feed and fuels. Demographics and climate change also drive the energy and transport sectors, and overall many commodity prices are expected to rise again. Potentially at odds, our agricultural and biofuel industries must not compete for land. We must raise the productivity of our lands such that all uses can flourish. It is the intelligent reallocation of our land to different uses that will allow our supply of agricultural production to both feed and fuel our populations. That reallocation must be predicated on detailed analysis of current land use, the capacity of given lands under certain constraints, such as water, fertility, and climate and sustainable land use policies. While technologies, management, and certain practices are proven to raise yields, they are poorly deployed. A lack of investment, misguided agricultural policies and subsidies, and lack of farmer education, training, and adoption has led to low agricultural productivity in much of the world.

The opportunities to increase production are diverse both in terms of geography and impact (Exhibit 2 and 3). Each category represents an investment opportunity for agricultural funds as well as other institutions. With proper policy guidelines in place that encourage farm modernization, free markets, and technology adoption, the production gap can be closed, but it is a large task.

EX 2: Opportunities for closing the production gap

Investment opportunities for closing the production gap

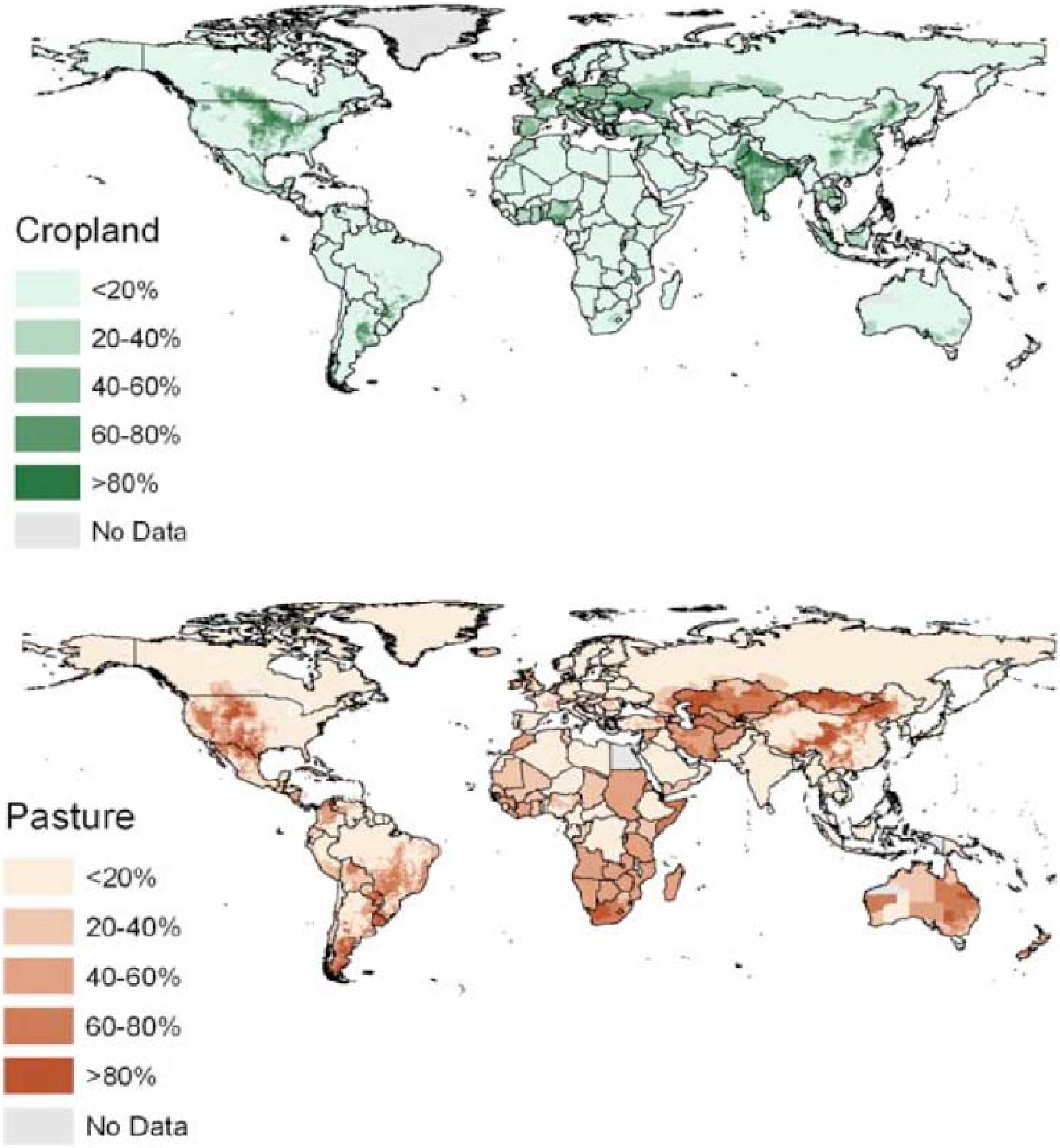
	Description	Impact	Geography	Type of investment
1	Irrigation	Raises productivity in certain regions	Regional, global	Technology, manufacturing
2	Fertilizer	Raises productivity in certain regions	Regional, global	Technology, manufacturing
3	Machinery	Enable more efficient farming	Local	Engineering, manufacturing
4	Commercialization	Raises productivity in certain regions	Global	Logisitics, manufacturing
5	Infrastructure	Major challenge to agricultural expansion, especially in emerging economies	Global	Governments, engineering
6	Land Expansion	Increase acreage for production	Global	Private lands, public lands
	Biotech Crops	Crop protection, drought resistance, disease resistance, lower water & fertilizer input	Choice by region	Biotech, agronomic

Investment Enablers

	Description	Impact	Geography	Type of investment
1	Education and practices	Adoption of technology and management	Local	Necessary for smaller farmers
2	Policy	Significant impact on agriculture	Global	Necessary for smaller farmers

Source: DBCCA analysis, 2009.

EX 3: Land supply for crops and pastures



Source: Ramankutty, 2008.

The Agricultural Challenge: Meeting the Demand

Recent research on global agricultural trends points to growing demand as the reason for higher food prices. Many studies and reports have shown that world population and GDP are growing, and as a result, diets are including more protein and calories overall (FAO 2008). In addition, government mandates for increased use of biofuels in transportation have diverted agricultural production to biofuels (Dufey, 2006). As a result of these trends, a “food-versus-fuel” debate emerged last year, but has since been muffled by falling oil prices. While only ~4% of global grain and oil seed were used for the production of biofuels in 2007 and 2008, forecasts of growing demand for agricultural products raise the question of whether supply-side forces can boost agricultural output enough to accommodate both increased food demand and biofuel mandates. If so, what are the investment implications of such forces?

Agriculture has transformed the planet (Foley et al. 2005, Monfreda et al. 2008), and in addition to supplying food, fuel and fiber, it has had profound effects on essential conditions for human health and well-being, such as water quality and supply, atmospheric composition, biodiversity, and regional temperature and precipitation. With respect to greenhouse gases (GHGs), agricultural practices such as deforestation and the use of certain fertilizers currently account for about 25% of global GHG emissions. In some cases, agricultural practices are unsustainable, using soil and water resources much faster than they are replenished, thereby reducing the capacity to grow crops in the future.

> *“Human land use practices, especially those tied to agriculture, have transformed the biosphere. The 40% of terrestrial photosynthesis appropriated for human use, the 50% of the global nitrogen flux from synthetic fertilizers and fossil fuels combustion and the freshwater withdrawals that exceed 50% of the accessible supply lead to the same conclusion: Never has a single species had such a planetary presence. Although we know much about the magnitude of the human transformation to the biosphere, we know little about its exact location and geographic manifestation.” (Monfreda et al. 2008)*

Although agriculture has shaped our world, it cannot be effectively analyzed as a single entity on a global scale. Agricultural systems vary dramatically between areas of different physical geography and socio-political characteristics, and regional differences will therefore be key determinants of the environmental outcomes of agricultural growth. Investors and policy makers interested in agricultural productivity should consider key regional factors, including landscape differences in growing conditions, differences in crop yield, carbon sink capacities, and differences in technology and agricultural methods. These differences may determine the success of new agricultural ventures that arise in response to increasing demand for food, feed, and biofuels.

Aggregate supply/demand relationships of agricultural production are notoriously complicated. We estimated the global per capita consumption/production demand for food and fuel in 2015 and 2050 (See Exhibit 1). Using reported food and biofuel demand growth rates, we found that the global demand of total calories requires a 50% increase over total calories produced in 2000 (FAO, 2008, FAOSTAT, 2008, FAPRI, 2008). This exercise is instructive as it helps us frame the problem in terms of agricultural productivity and begin to focus on systemic levers to increase production. But whille long-term aggregate level analysis is a good starting point, it is important to develop an estimation of the dynamics between land use, yield growth, and commodity prices.

EX 1: Aggregate supply and demand relationships

Compounded rates of growth

	2000-2015	**2015-2050**
Food growth	1.50%	0.90%
Population growth	1.10%	0.60%
Per capita use of food (1)	0.40%	0.30%
Biofuel growth	3.30%	1.80%

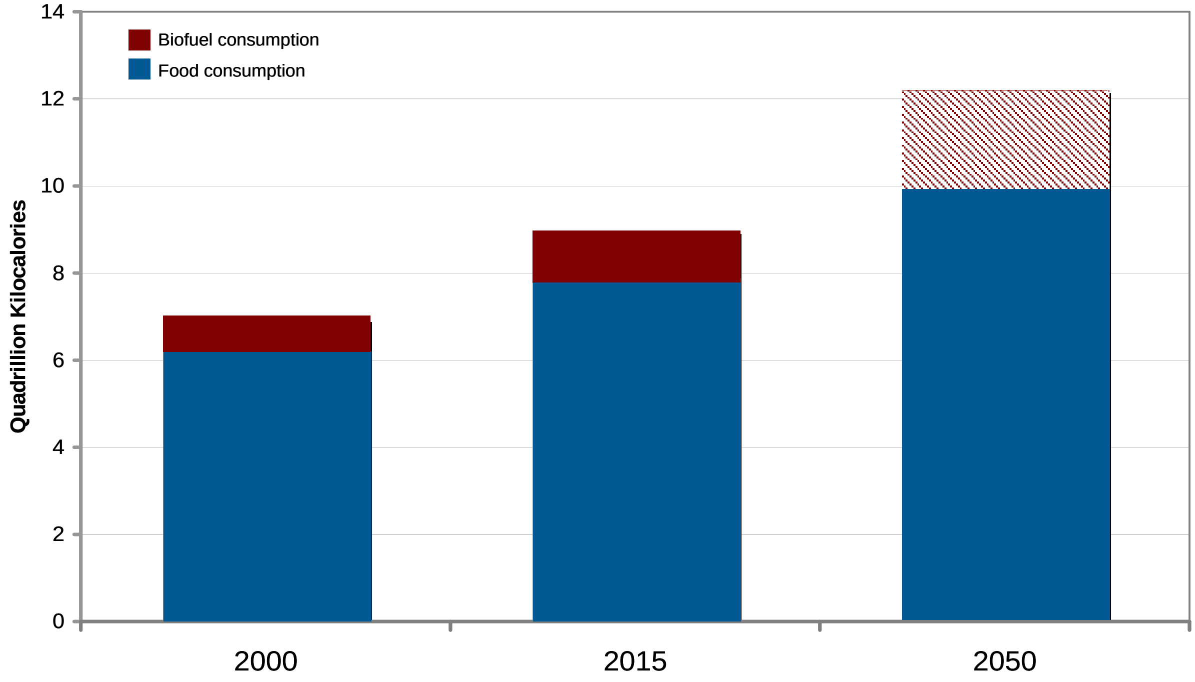
Note: (1) Includes the effects of growing income, dietary trends, and relative prices with no net change in stocks.

Food and biofuel consumption

	Food consumption	**Biofuel consumption**	**Percent of biofuels of total kcal consumption**
	(Quadrillion kcal)	*(Quadrillion kcal)*	*(%)*
2000	6.21	0.74	10.60%
2015 (est)	7.78	1.2	13.40%
2050 (est)	9.93	2.27	18.60%

Note: Biofuel consumption for 2000 and 2015 were derived from FAPRI statistics, while the estimate for 2050 consumption was extrapolated from the growth rate in biofuels between 2000 and 2015.

Production gap of food and biofuels



Source: DBCCA analysis, 2009.

The Agricultural Challenge: Meeting the Demand

Our analysis seeks to understand the regional constraints on raising agricultural productivity in the context of current global shifts in demand (Exhibit 2). We consider the geographic location of agricultural productivity and lay out a framework for assessing potential growth with minimal negative environmental consequences. With this analysis, we can determine where we expect productivity can be increased by irrigation, fertilization, and use of advanced genetics and biotechnology. We also show how other lands are suitable for biofuels production. Furthermore, we outline some growing opportunities in the agribusiness sector that will lead to improved efficiency and enhanced productivity.

EX 2: Supply and demand factors influence our food, feed and fuel production/distribution systems

Supply and demand factors influence our food, feed and fuel production/distribution systems

Demand factors	Supply side responses	Constraints
• World population is growing • World GDP per capita is growing • Global increase in protein consumption • Increased demand for biofuels • Inclement weather	• Expansion of land acreage • Fertilizers • Irrigation • Biotech crops • Machinery • Food system efficiency	• Water availability • Environmental, i.e. Nitrogen, salinization, eutrophication, pests • Land ownership • Carbon constrained economy • Climate change

Source: DBCCA analysis, 2009.

Researchers from the Massachusetts Institute of Technology (MIT) constructed a general equilibrium model to determine aggregate supply/demand relationships and used land prices as a means to convert from one agricultural land use to another (Gurgel et al., 2008). They concluded that with a climate change policy constraint and minimal deforestation, biofuels would have to specifically displace pasture-lands in order to increase food and feed production to meet demand (Box 1). However, the challenge to the global equilibrium models is that they underestimate the complexities of local land use change and patterns of productivity.

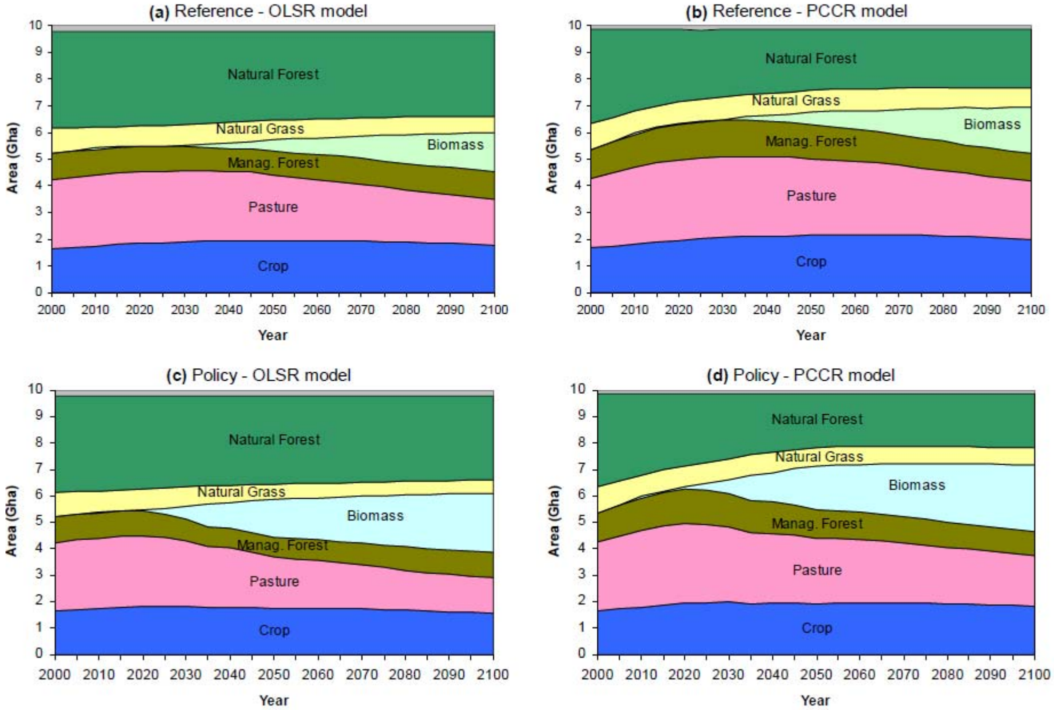
Additionally, researchers from the Potsdam Institute constructed an alternative model that sought to reallocate land-uses to the most productive regions of the world (Box 2). And in Box 3, we discuss the alternative of a more distributed food system such as those promoted by sustainable agriculture projects that is characterized as organic, local, multi-crop, energy and water efficient, low-carbon, socially just, and self-sustaining.

Box 1: Synthesizing Demand and Supply in Agriculture – The MIT Model

In order to understand better the roles of supply and demand for agricultural resources, a general equilibrium model has been developed as an extension of the MIT Emissions Prediction and Policy Analysis (EPPA) model (Paltsev, 2005). The model addresses energy, agriculture and climate change policy and in this case, includes multiple agricultural sectors and land types where supply and demand solve at certain land price levels. The demand factors are based on population and income trends, while supply is based on land supply and productivity. The investigators explicitly used second generation biofuels production as it becomes a feasible substitute at ~5 times the yield of maize. Also, the model is first run unconstrained for carbon and then run with a carbon "cap" of 550ppm CO_2. Agricultural productivity is assumed to grow around the 1% p.a. level of recent trends. The model allows for any land to be converted to any other use, or can be constrained to reflect recent land usage which reduces the amount of deforestation.

The charts below show 4 scenarios for land use during this century:

a. No climate change constraint, current land usage (limited deforestation) maintained (OLSR: Observed land Supply Response).
b. No climate change constraint, no land use constraint (PCCR: Pure Conversion Cost Response).
c. Climate change constraint 550ppm (CO_{2E}), current land usage (limited deforestation) maintained (OLSR: Observed land Supply Response).
d. Climate change constraint 550ppm (CO_{2E}), no land use constraint. (PCCR: Pure Conversion Cost Response)



Source: MIT Emissions Prediction and Policy Analysis (EPPA) model; Paltsev, 2005.

The scenario we expect is [**c**] where deforestation is minimized and there is a climate change carbon constraint. In this instance, biofuels will specifically displace pasture land, some natural grasses and potentially, managed forests. It is interesting to note that since second generation biofuels will use grasses and wood, biofuel feedstock production land may overlap with grassland, crops and managed forests, but leave room for food supply. Increased productivity of pasture is also an option. For instance, in Argentina and Brazil, generally, 1 beef animal grazes a hectare, and increasing to 2 cattle per hectare may be feasible since there is sufficient water in Latin America. Food prices, perhaps the key political variable and a key operational variable for poorer nations and people, do not increase significantly in the long –term policy-OLSR scenario. In fact, overall crops, livestock and food prices only rise around 15% over the course of the 21st century, and only about 5% of that could be attributed to biofuels.

"Our modeling also reflects longer-run elasticities that give time for the sector to adjust, and over the longer term agriculture has proved very responsive to increasing demand… We also expect less direct effect on corn prices because corn-based ethanol directly affects the corn market whereas cellulosic crops would only indirectly affect crops through the land rent effect. In this regard, our simulations suggest that is possible to integrate a substantial ethanol industry into the agricultural system over time, without having dramatic effects on food and crop prices. And it is even possible to do it without converting large amounts of natural forest…"

The Agricultural Challenge: Meeting the Demand

Box 2: Alternative Scenarios: Radically Change Global Land-use to Comply with Climate

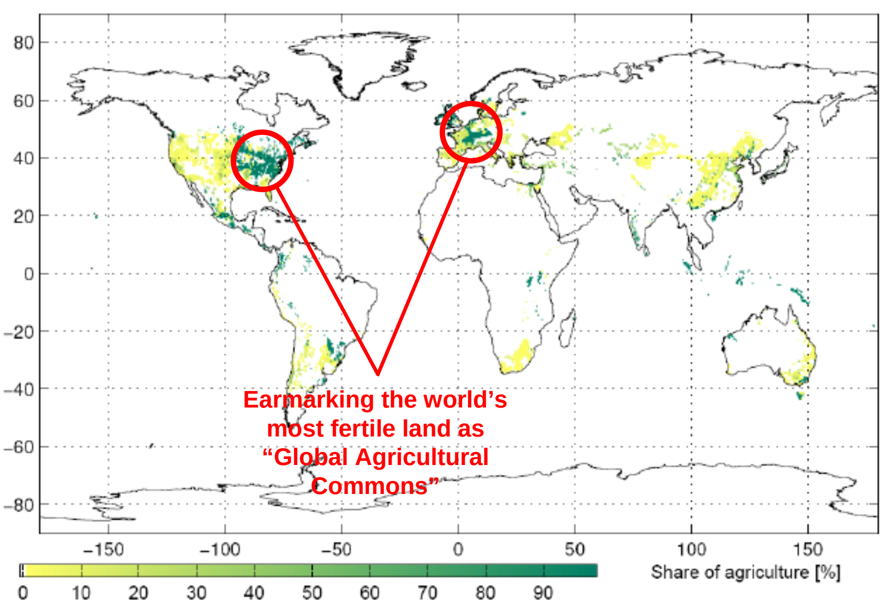
In our land-use study we derived land productivity capacity from a base line dataset developed by SAGE who identified areas with the largest production gaps. What if we started from a clean slate and produced the agriculture goods that we needed from the most optimal regions on earth based on climate, soil and water constraints, without regard to existing infrastructure or agriculture development.

The Potsdam Institute for Climate Impact Research conducted such a study using a linear optimizing model across a landuse database. They ran various land-uses scenarios under varying market conditions. To represent an unrestricted global agricultural market (no trade barriers, no transportation costs, no subsidies) as a first setting, production was allocated to the most productive regions (globalized production). In a second setting, production was allocated locally (localized production); that is, they forced each region to satisfy, as far as possible, its own demand (population multiplied with the corresponding regional per-capita demand). From this they, derived different demand patterns by doubling and/or halving the present-day values of population and consumption of animal products. Comparing these approaches identified the potential impact of different global land use patterns as they may result from a globalized or regionalized world economy. The study demonstrated that the individual effects of different drivers of land use change (demography, diet, production pattern) are of major importance for the global carbon and water budgets (M¨ller et al 2006).

By optimizing production, they found that concentrating agricultural production to the most productive sites could provide the needed production to feed growing populations (See charts below). The general result is that land use pattern is an important factor in the global carbon balance. Agricultural land use is a major factor influencing the global carbon and water cycles, and in the case of carbon, it is potentially equally important to historic fossil-fuel emissions and projected climate change. By showing that demand structures, driven by population and consumption patterns, significantly affect total agricultural area and the carbon and water budgets globally, they conclude that the spatial location of agricultural land is the most important determinant of area demand and thus of the biogeochemical impacts of land use. While a globalized production scenario may be analytically attractive, however, the globalizing or localizing of production could have other implications for carbon and water cycling such as transportation, fertilizer and pesticide production etc.

The alternative models of land-use allocation shown below are important tools for policy makers. While a complete overhaul of how land is used on a global basis may be impractical in the short-run, long-term planners of agricultural development need to consider the carbon-water balance in their efforts to increase agricultural productivity.

Globally optimized production scheme (population of 12 billion, diet of 1995)



Source: Muller et al. 2006.

Box 3: Alternative Scenarios: Grow Local, Grow organic

Much of this report focuses on Business-As-Usual (BAU) development of the industrial agri-business complex. There are however, and according to many, compelling and critical alternative food systems which require our attention and our implementation.

An alternative food system would revitalize the family-farm, produce fully nutritious food and foster the relationship between people and nature. These alternatives have been written about extensively in recent publications such as Eric Schlosser's Fast Food Nation, Michael Pollan's The Omnivore's Dilemma and In Defense of Food and the many of the essays of Wendell Berry. Many research centers and institutes such as the Aldo Leopold Center for Sustainable Agriculture, The Land Institute, the Stone Barns Center, as well as many movements such as Slow Food, The Edible Schoolyard, and other Sustainable Agriculture projects have all cropped up to promote a healthy and sustainable food system. That food system would be characterized as organic, local, multi-crop, energy and water efficient, low-carbon, socially just, and self-sustaining.

Critical areas of debate include the monocultures of our agriculture system, the inputs we use to produce food, including genetically modified organisms (GMO's), and the environmental impacts of our production. One critical area of the debate is the use of science in the pursuit of improved productivity. In a note entitled a Tale of Two Botanies Amory Lovins and Hunter Lovins point out the potential perils of transgenic crops (GMOS's) and warns us of the dangers of the acceleration or perturbation of evolutionary pathways. Furthermore, the use of fertilizers, pesticides and other agro-chemicals have been implicated in severe human health impacts written about in Theo Colburn's Our Stolen Future.

An alternative food system is a resource and ecologically efficient system of farming and preparing foodstuffs. This would include a revamping of the farm-to-food system, where production methods would be less resource-intensive, food would be grown and consumed locally and on a seasonal basis, and communities could participate in the growing of their food through local co-ops, farmers; markets or CSA's (Community Supported Agriculture). But most of all, food production would be a less resource intensive enterprise that better mimics ecological systems rather than today's industrial system.

For example, organic farmers rely on healthy soil and controlling pests, not the elimination of pests. They also make efforts to restore and sustain natural capital through their farming practices. Agriculture based on natural models could reduce land clearing and fertilization and could be more reliant on renewable energies, such as solar and wind and be more judicious and efficient with the usage of water for irrigation. Additionally, livestock management would require changes in tax and subsidy policies, improve the humaneness in which animals are raised through free-range pasturing, and many other techniques.

Recently, the United Nations Food and Agriculture Program (FAO) released a report on how organic agriculture can not only mitigate greenhouse gas emissions but also can reduce soil erosion, rehabilitate soils, conserve biological diversity, reduce environmental degradation, lower livestock densities and create more effective vegetable production and integrate farmers into high value food chains. Additionally, researchers have found that organic agriculture has the potential to contribute substantially to the global food supply while reducing environmental impacts. Practices included crop rotations, rotational grazing, and low-external input production (Badgley et al., 2007).

As we have stated, the grand challenge of feeding 9 billion people requires scalability and the question is whether these systems can scale.

Return Dynamics

Agricultural returns are influenced by two main drivers: prices and productivity. Rising prices will boost the incomes of farmers, many of whom are low income earners globally, but also affect the ability of many poorer people to pay for their basics. Hence this becomes a heated issue quickly. Given our view that the long-term demand will outpace productivity growth as a major supply side response takes place, it is likely that prices are going to rise again. The optimal solution is a gradually rising price level encouraging investment which gives a strong return to farmers and investors but is manageable from an equity standpoint. However, agricultural markets are famous for their short-term cob web structure – relative excess demand influencing prices before investments can adjust and respond on the supply side, leading to the potential for price volatility.

In this section we explore some of these dynamics historically, particularly looking at the price bubble of 2008. Then looking to the future we believe that even with continued shorter term volatility, real prices will continue to rise on a long term trend which will indeed encourage the investment needed to bring on new capacity in yield and land supply. These forces offer a positive outlook for investors with moderate correlations to equity markets.

Role of Prices

Historically, returns in agriculture have shown low correlation to equity markets (Exhibit 3). This is true of investments in production itself but less so for publicly listed agro-conglomerates. The combination of land price appreciation plus increases in productivity have led to long term investment returns.

EX 3: Correlations of sector real growth with real GDP growth

Correlations of sector real growth with real GDP growth

	1978-2006
Private industries	0.99
Agriculture, forestry, fishing and hunting	0.2
Farms	0.2
Forestry, fishing and related activities	0.07

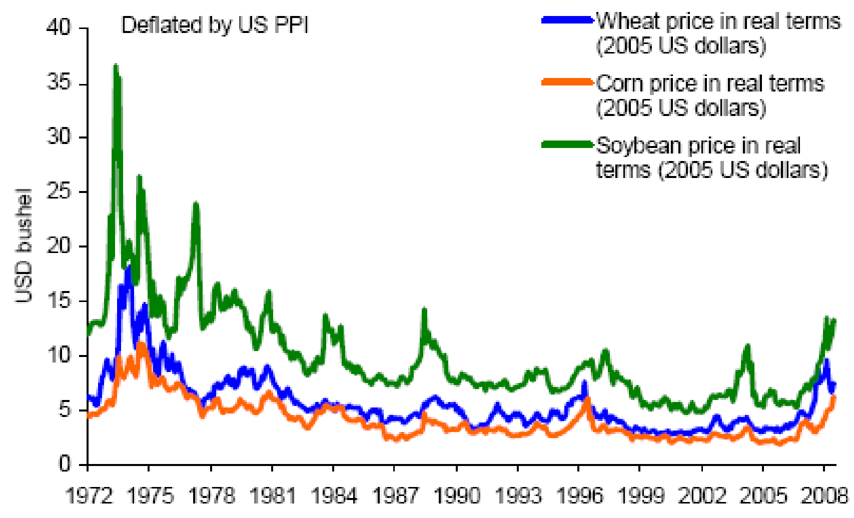
Correlations with real GDP growth

	Total Ag	***Farms***	***Other***
1948-2007	0.04	-	-
1978-2007	0.2	-	-
1978-2006	0.2	0.2	0.07
1985-2006	0.34	0.33	0.14
1990-2006	0.4	0.39	0.18

Source: DBCCA analysis, 2009.

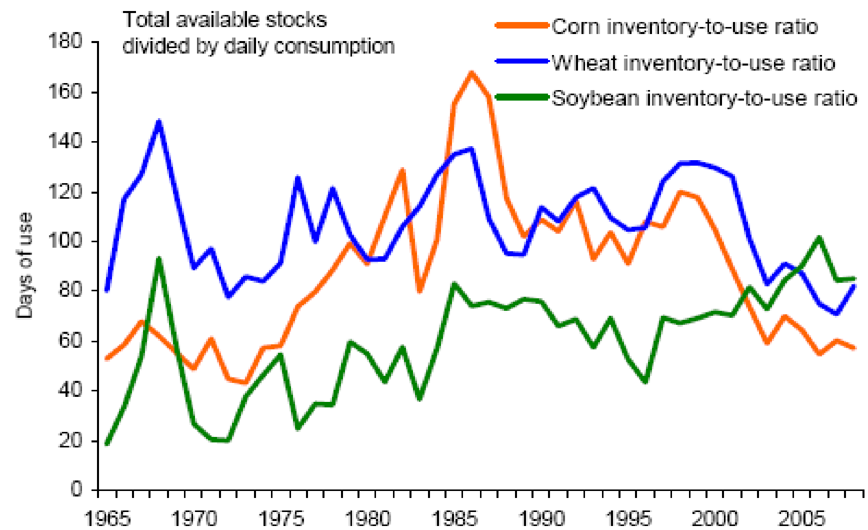
Agricultural commodity prices are often volatile in the short-term, displaying large spikes in prices. Input prices, such as fuel and fertilizers in the developed world, are often drivers of these spikes. Yet, in the long-term, in real terms, these commodity prices have remained relatively flat (Exhibit 4). While it may look like not a lot of positive returns were happening in agriculture, per acre returns went up significantly, indicating an increase in productivity (USDA-NASS, 2009). However, in today's world, where current available commodity inventories for corn is just 47 days of consumption (Exhibit 5), we believe that that prices in real-terms will begin to rise. Increasing consumption of food crops, shifting diets towards more protein, climate and weather-related spikes, and any diversion of food crops to first generation biofuels will put pressure on these commodity prices. And in the face of these pressures, governments worldwide may continue to erect export barriers in order to guard against domestic food shortages, all leading to increases in real prices.

EX 4: Agricultural prices in real terms still remain low compared to the 1970's



Source: USDA, 2009.

EX 5: Inventory to consumption ratios

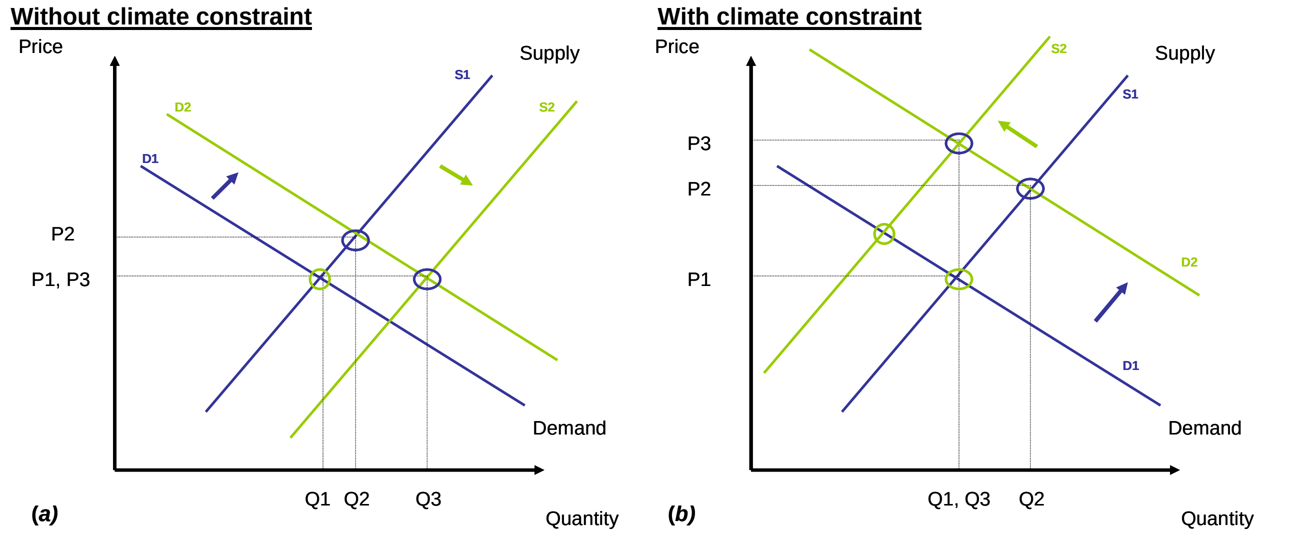


Source: USDA, 2009.

Traditional economic models of price movements of commodities show responses to these pressures by following the classic cob web interaction of supply and demand out of equilibrium. In many areas of agriculture, supply can adjust to demand shocks within a growing season or two by reallocating land to different crops, optimizing inputs and other agricultural management practices. With the growing demand as outlined above coupled with production pressure from climatic shifts (as explained later), we now expect that productivity growth will be unable to keep up with demand growth, as in the past, thereby leading to an increase in prices. For example, we illustrate a simple Supply/Demand curve analysis in Exhibit 6. In scenario (*a*) with increasing demand (D1 moving to D2) and constant production as it exists today (S1), we would expect prices to rise (Q1,P1 goes to Q2 P2). As we raise productivity (S1 goes to S2) and bring production to meet growing demand, food prices can stabilize (Q3,P3) . However, in a scenario where supply is unable to meet demand (*b*), as in a climate change scenario without strong adaptation and mitigation programs (described later), we expect real prices to rise (Q3,P3) as demand growth exceeds productivity growth in the long-term (Exhibit 6).

And it is this rise in prices that also will stimulate investments in the supply-side response. In both price cases, flat or rising, the strong investment returns from agriculture will have to come primarily from increases in productivity. Technological and management improvements can lead to higher productivity rates. And as production per unit of input land increases, revenue will increase, and thus higher investment returns. While these models help us think about production scenarios, we expect that the cycle of overshoot of supply and demand will persist and that in the face of growing pressures on our agricultural systems, the likely outcome in the long-run, will be an increase in prices.

EX 6: Supply-Demand Curve Scenarios



Source: DBCCA analysis, 2009.

Recent market dynamics

Over the long-run the thesis remains intact that there will still be an uptrend in food prices and that a long-term supply side response is needed to keep long-term equilibrium for demand/supply and price in acceptable bounds for investors and consumers. However, we need to explain in detail what happened in 2008 to better understand how the sector is subject to short-term market movements, and to inform investors that the short-term correction is an excellent opportunity to invest in the long-term secular trend.

Short-term dynamics of price movements are evident in recent years. Over the past three years agriculture commodity prices, as measured by the DB Agriculture Index (Exhibit 7), and businesses, as measured by the DAX Global Agribusiness index (Exhibit 8), have risen sharply. Investments in these sectors over the period leading up to what can be viewed as the bursting of a bubble were seen as non-correlated asset classes, and returns in these investments were driven by the perceived expansion of global demand for food and biofuel. During the beginning periods of this cycle, agriculture would have made an excellent investment (Exhibit 9).

Agriculture: Economic and Financial Attributes

We view the bubble in agricultural prices in the context of the 100 day rolling correlation of corn price (as a proxy for agriculture) to oil. We found that as oil prices rose significantly, the correlation of agricultural commodities to oil also rose significantly (Exhibit 10 and 11). This spike in corn prices began in October 2006 and ran through the peak of June 2008, when correlation with oil prices was at an all time high. This correlation between food prices and oil prices remained intact as the global recession hit and oil prices dropped. This rise in food prices was debated extensively, often with biofuels seen as the culprit. Moreover, panics and hoarding of rice were well documented in the press (Exhibit 12). These events, we believe, neglected the real long-term build-up in demand for food and fuel for demographic and climate change reasons.

In 2008, the agriculture sector was tremendously volatile. This volatility occurred as the correlation of the sector to oil overshadowed traditional fundamental drivers. Soft commodities, such as corn and soy, and related supply chain companies, began to take on bubble-like characteristics (Exhibit 13). Investors focused on these two groups as the increase in the oil price and the far-ranging potential of China's infrastructure build-out became more apparent. In addition, almost all commodities are priced in US dollars. With the dollar's drop to historic lows over the summer of 2008, the bullish momentum increased dramatically, exacerbated further by the influx of index money into commodities.

Although the origin of this volatility was in part due to oil, the increases were felt throughout the agriculture sector. Exacerbated over the past few years by the oil/ethanol substitution effect, increased production of corn-based ethanol was encouraged (Exhibits 14 and 15). The increase was both driven and amplified by government subsidies and tariffs. The increasing demand motivated farmers to substitute corn for other crops. In order to profit from the record prices, farmers strove to maximize yields by increasing application of fertilizers, using genetically modified seeds, installing new irrigation systems, and upgrading farm equipment. These efforts caused price spikes further down the supply chain for related services such as transportation and storage. This demand-based pull for related goods and services pushed the price spike beyond corn. In addition, the rapid increase of agricultural commodity prices caused adaptive behavior among downstream participants. Food companies were squeezed by high input costs, such as transportation, and livestock farmers culled herds in the face of increasing feedstock costs.

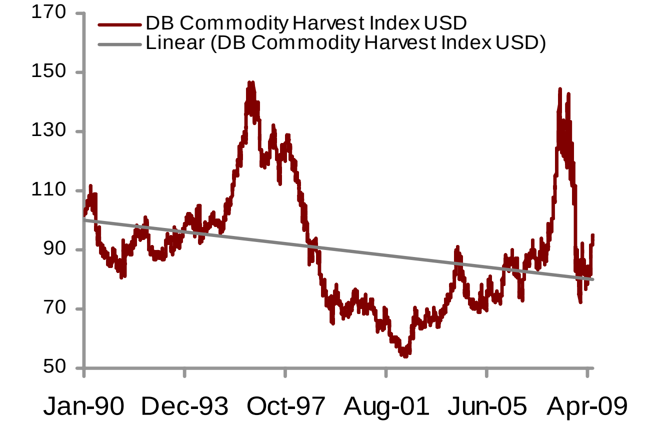
The rapid increase in prices was finally halted when key elements of commodity price support decreased almost simultaneously over the summer of 2008. The demand for oil dropped globally as the financial crisis began to impact the economy, the European Central Bank indicated that it would halt interest rate increases sparking the reversal of the Dollar/Euro exchange rate and yield expectations in the US corn belt were not as bad as was earlier thought. And in the fourth quarter of 2008, oil, along with most other commodities, sold off almost as rapidly as it had increased earlier. Economic weakness, the credit crunch and the decline of energy prices impacted agriculture dramatically.

Future Outlook

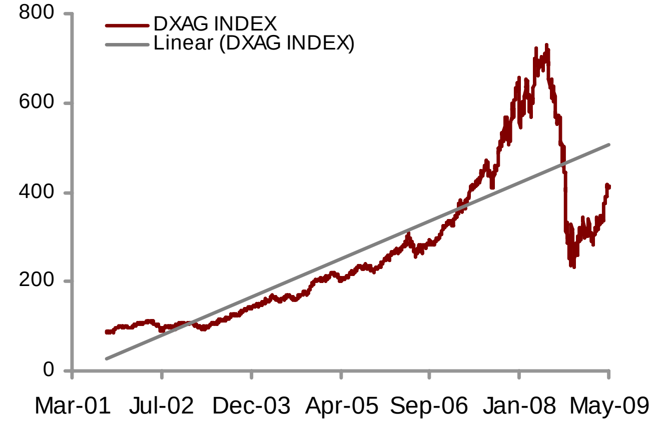
As we have seen in the recent market cycle for agricultural productivity, prices and investment returns are inextricably linked through a supply-demand overshoot cycle. It is our view that these cycles will continue to manifest themselves and become more acute as the population grows and productivity is impacted by climate change. The key will be to continue to raise productivity and this will be partially driven by increases in prices. As investors, it is important to be sensitive to this cycle of overshoot in order to capture returns in the fluctuating price-productivity relationship. A price driven strategy would include an understanding of how productivity increases and how those yield improvements drive returns in investments. Innovation and adoption of technologies can lead to improving returns per unit of land and these improved returns ultimately result in improved investments returns.

While commodity prices have come down and are projected to remain somewhat flat over the next year, our long-term view of agricultural and indeed energy-related commodities is that they must continue back in an upward trend. This will ultimately restore the increasing long-term value trend of agri-complex companies. In the near-term, agricultural commodity prices may remain flat due to their correlation with oil prices and a weak economy. These trends make investing in the agricultural sector somewhat volatile in the short term, but we believe that the long-term demand of a growing population will reward a supply side investment response in productivity.

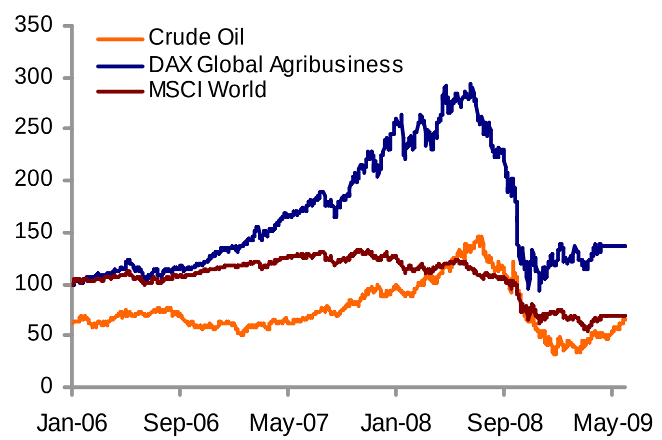
EX 7: DB Agriculture Commodity Price Index



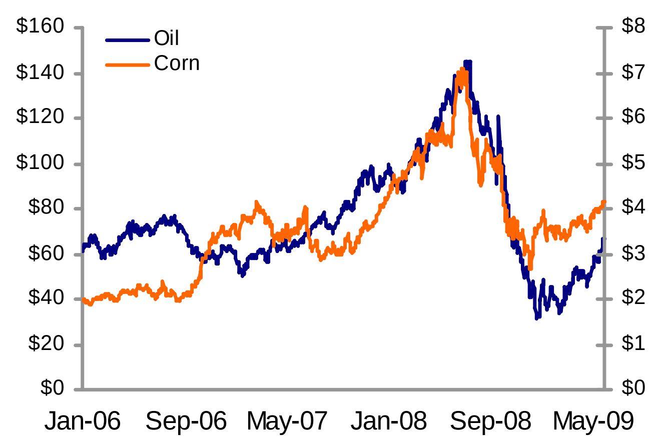
EX 8: DXAG Company Index



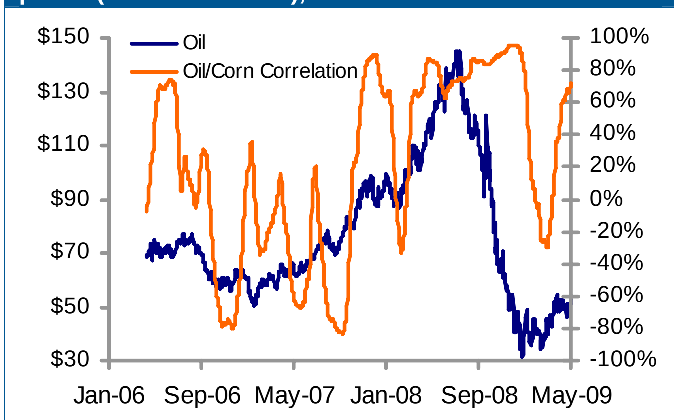
EX 9: Comparative performance of energy & agriculture



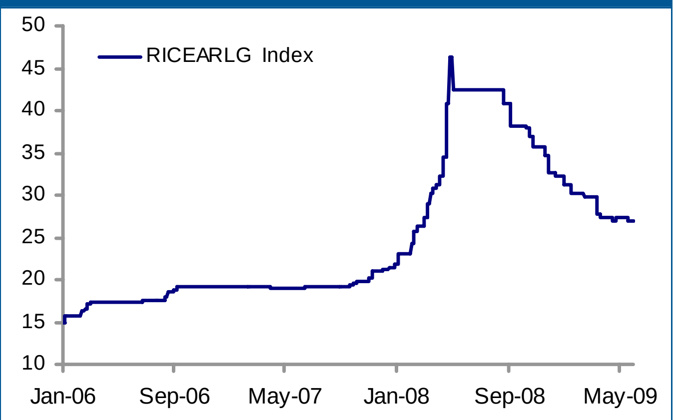
EX 10: Performance of corn and oil prices



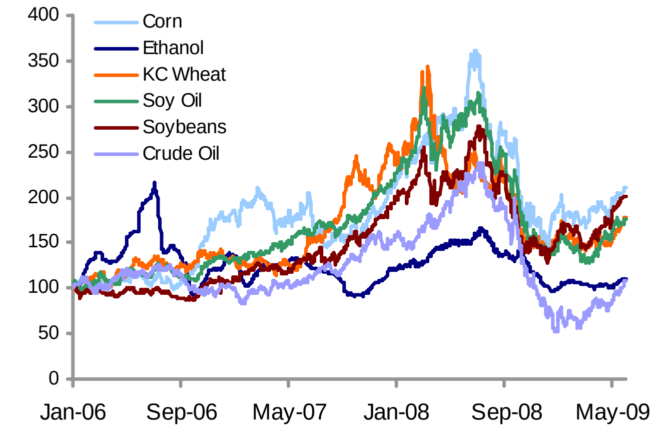
EX 11: 100 day oil/corn rolling correlation daily agric. prices (1/1/06 – 04/09/09), Prices based to 100



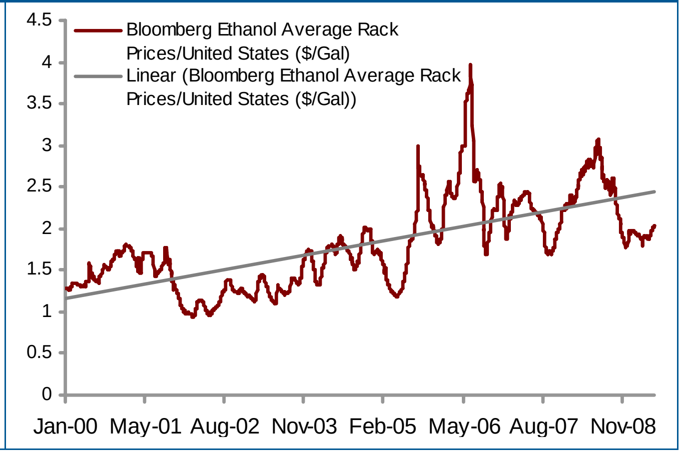
EX 12: Performance of rice prices



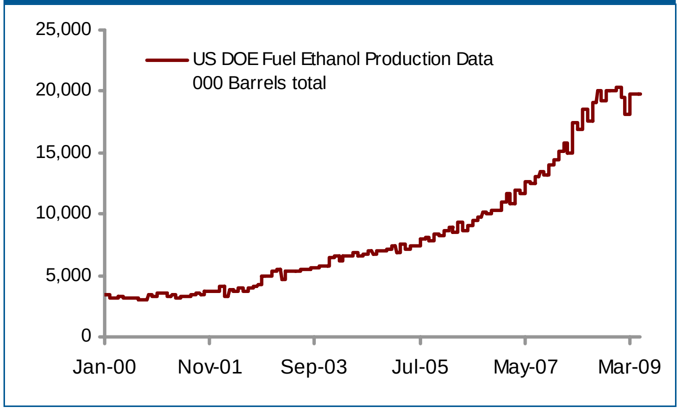
EX 13: Performance daily agriculture prices (1/1/06 - 04/09/09), Prices based to 100



EX 14: Performance Ethanol Price Index



EX 15: Ethanol production

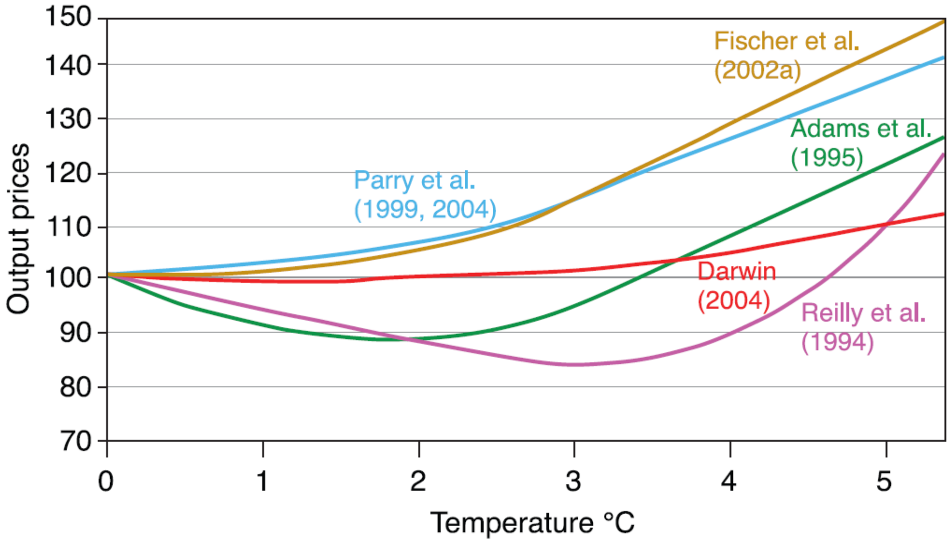


Source: Exhibits 7 – 15: Bloomberg, DBCCA analysis, 2009.

The global economic recession coupled with the climate crisis continues to challenge every sector of the economy and society. Nowhere is this more true than in the agriculture sector. The growing demand for increased agricultural productivity, driven by population growth, a shift in dietary preferences as a function of increased wealth, and an increased demand for biofuels, suggests that agriculture, and the investment opportunity in agribusiness, have a key role to play in the economic recovery and in mitigating as well as adapting to climate change.

The changing patterns of climate can potentially have severe impacts on agricultural productivity both ecologically as well as economically. Due to shifting precipitation patterns, movement of insect populations, more dramatic shifts in daily temperature regimes, and other large scale ecological changes that come with climate change, agriculture is the economic sector that will be most severely impacted by climate change. For example, there are various studies have shown that increase in global average temperatures could have significant impacts on cereal prices (Exhibit 16, IPCC, 2007).

EX 16: Cereal prices (percent of baseline) versus global mean temperature change



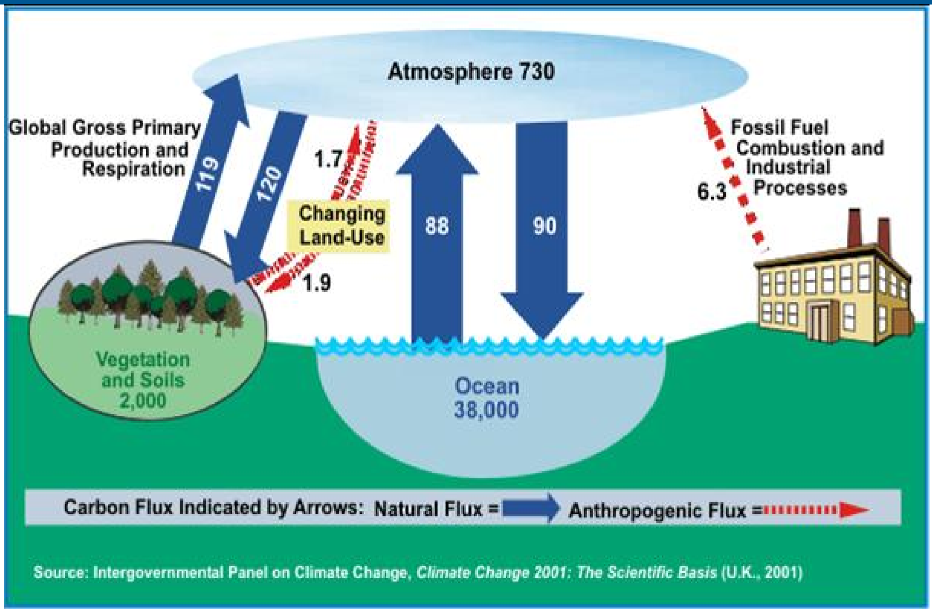
Source: IPCC, WGII, 4th Assessment. Note: From major modeling studies. Prices interpolated from point estimates of temperature effects.

Climate change impacts agriculture through potential variation in temperature regimes. These regimes can alter yield patterns, and cause increased crop damages, soil erosion, and overall land degradation. These changes will require adjustment of planting dates and crop variety using dynamic planning tools for crop relocation, and improved land management. Research and development on polices, land tenure reform will also be required for ease of transition. Training of farm communities and capacity building through crop insurance and financial incentives, such as tax credits and subsidies, will help overcome the social barriers to adaptation.

Changing precipitation patterns and the shifts of regional weather to be hotter and drier in some regions while other regions become more moist will cause severe challenges to existing agricultural systems. Lobell et al. 2008, described how warmer climates will harm yields. Also, Schlenker and Roberts (2005) estimated that the probability of increased warmer temperatures would occur in developing regions of the world disproportionately. Losses of as much as US $5 billion a year have been estimated from farmland value (dryland) due to changes in temperature and precipitation (Schlenker et al. 2005).

Emissions from agricultural activities account for about 14 percent of global GHG emissions. This amount is divided roughly evenly between CH_4 and N_2O (about 45 percent each), with CO_2 from fossil fuel combustion and electricity use accounting for the remaining share. At the activity level, the largest agricultural source is soils management (40 percent of the sector total), where emissions result from particular tillage and cropping practices, such as fertilizer application. The second largest source is methane emissions from livestock (27 percent of the agriculture total), which is a byproduct of the normal digestive process of cattle and other livestock. Other important agriculture sources are wetlands rice cultivation (CH_4) and manure management (CH_4). Agriculture also contributes to CO_2 through land clearing and the burning of biomass. See Exhibit 17 for a diagram of the flux of carbon in agricultural systems.

EX 17: Carbon Fluxes in Agricultural Systems



Source: WRI, 2008; DBCCA analysis, 2009.

Our response to the impacts of climate change on agriculture needs to include not only the development of new agro-technologies, water management systems and farm practices, but also investment in infrastructure and logistics to facilitate the development of these adaptive agricultural systems. This type of investment requires innovative policy directives that can foster adaptation to climate change. One such policy is the separation of what is now being called agro-fuels (corn, rapeseed, soy, and palm) from cellulosic derived biofuels that do not compete with food for land.

Mitigation

The agriculture sector can participate in the mitigation of climate change in its ability to store and cycle CO_2, a potent greenhouse gas, and to provide potential offset markets for the trading/management of carbon. This can be done through a suite of technologies and management practices such as no-till cropland management, planting of perennials and the development of biochar resources (Exhibits 18 and 19). According to McKinsey & Company's Greenhouse Gas Abatement Cost Curve analysis, agriculture represents about 14% of global greenhouse gas emissions (6.2 $GtCO_2e$, per year with a growth trajectory of about 1% (Exhibit 20). This includes emissions from soils (in the form of nitrous oxide), methane from livestock, rice cultivation and manure management, as well as other agricultural practices such as open burning of crop residues. Estimates of the abatement potential from agriculture are actually quite significant (4.6 $GtCO_2e$ per year or 12% of global abatement opportunities) and represent a decline by 60% of sector emissions (Exhibits 21 and 22). These abatement levers include improved pastureland management, restoration of degraded lands, enhanced cropland management, and reduced methane emissions from livestock. Again, a policy response is needed to provide these opportunities to the agricultural sector.

EX 18: Opportunities for Carbon Mitigation (Source Pretty, 2008)

Increase carbon sinks in soil organic matter and above-ground biomass

- Replace inversion ploughing with conservation- and zero-tillage systems
- Adopt mixed rotations with cover crops and green manures to increase biomass additions to soil
- Adopt agroforestry in cropping systems to increase aboveground standing biomass
- Minimize summer fallows and periods with no ground cover to maintain soil organic matter stocks
- Use soil conservation measures to avoid soil erosion and loss of soil organic matter
- Apply composts and manures to increase soil organic matter stocks
- Improve pasture/rangelands through grazing, vegetation and fire management both to reduce degradation and increase soil organic matter
- Cultivate perennial grasses (60–80% of biomass below ground) rather than annuals (20% below ground)
- Restore and protect agricultural wetlands
- Convert marginal agricultural land to woodlands to increase standing biomass of carbon

Reduce direct and indirect energy use to avoid greenhouse gas emissions (CO_2, CH_4 and N_2O)

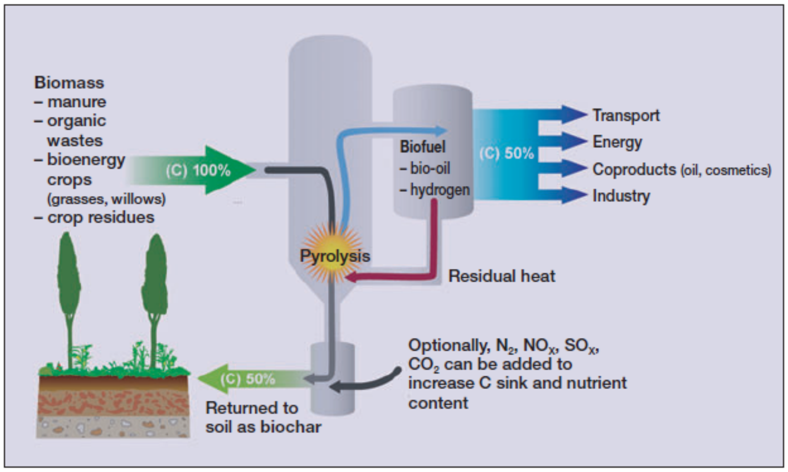
- Conserve fuel and reduce machinery use to avoid fossil fuel consumption
- Use conservation- or zero-tillage to reduce CO_2 emissions from soils
- Adopt grass-based grazing systems to reduce methane emissions from ruminant livestock
- Use composting to reduce manure methane emissions
- Substitute biofuels for fossil fuel consumption
- Reduce the use of inorganic N fertilizers (as manufacturing is highly energy intensive), and adopt targeted and slow-release fertilizers
- Use IPM to reduce pesticide use (avoid indirect energy consumption)

Increase biomass-based renewable energy production to avoid carbon emissions

- Cultivate annual and perennial crops, such as grasses and coppiced trees, for combustion and electricity generation, with crops replanted each cycle for continued energy production
- Use biogas digesters to produce methane, so substituting for fossil fuel sources
- Use improved cookstoves to increase efficiency of biomass fuels

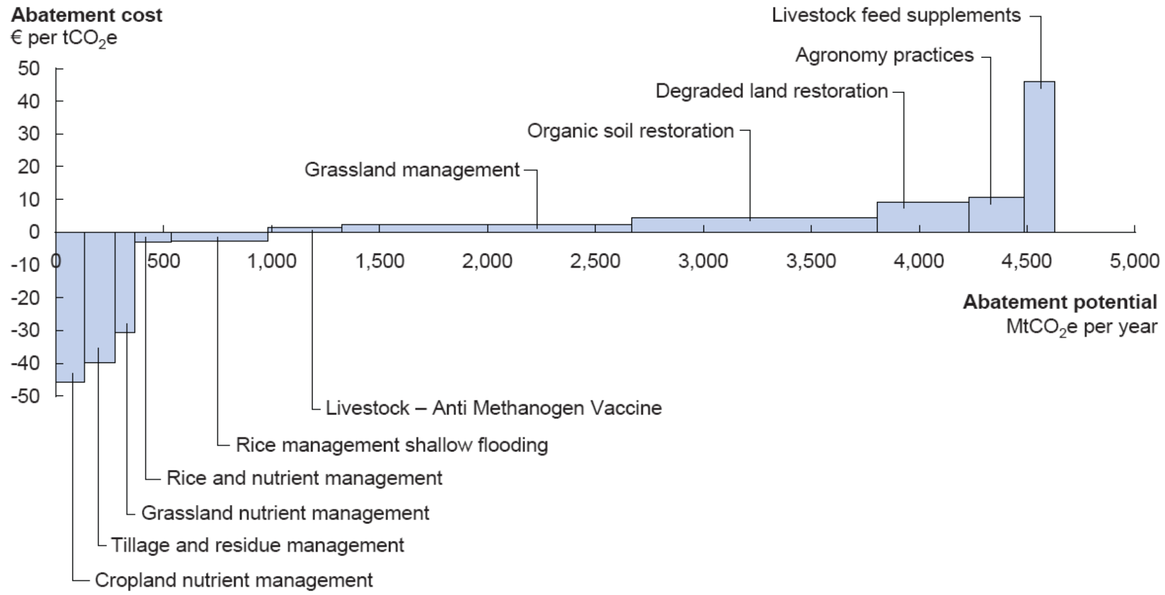
EX 19: BioChar

- A by-product of low-temperature pyrolysis bioenergy
- Biochar additions to soil reduce CO_2 emissions from energy production as well as withdrawal from atmosphere
- Increases global Net Primary Production from increased soil fertility and nutrient retention
- Reduces nitrous oxide emissions
- Can be co-produced from biomass energy residues



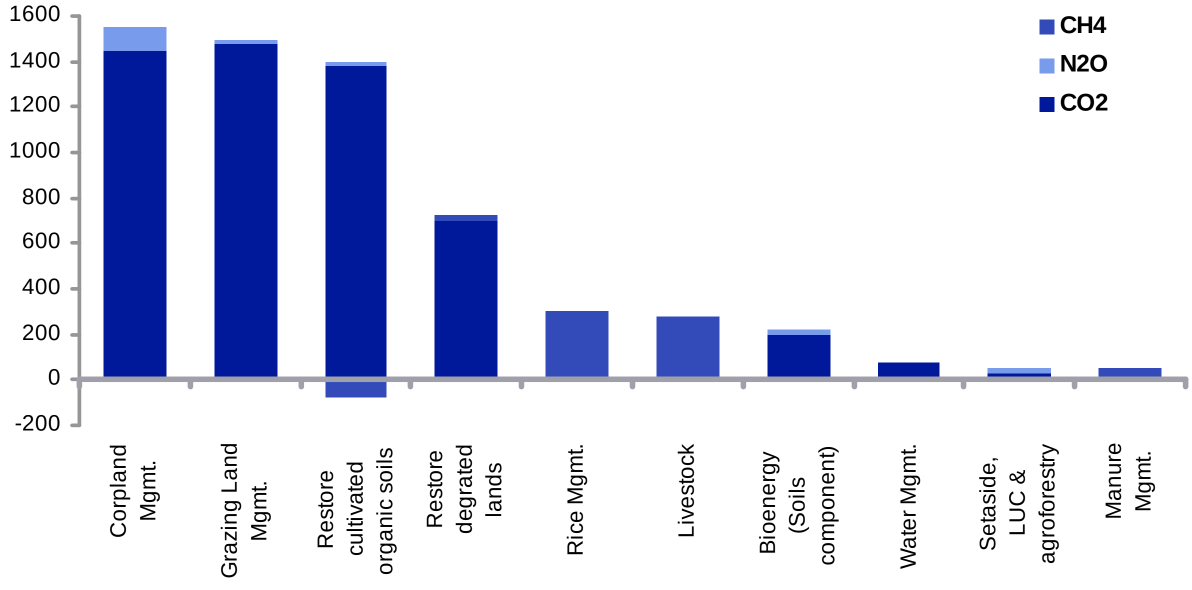
Source: Lehman, J. 2007.

EX 20: Global GHG abatement cost curve for the Agriculture sector, 2030



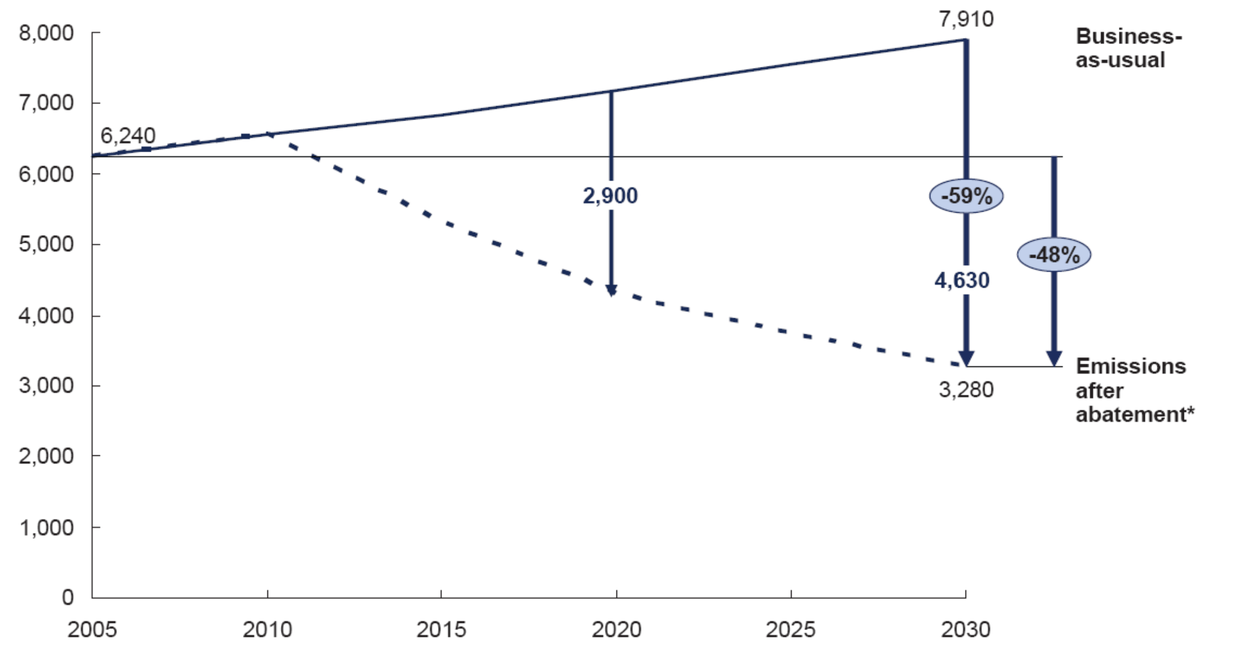
Source: Global GHG Abatement Cost Curve v2.0. Note: the curve presents an estimate of the maximum potential of all technical GHG abatement measures below €60 per $tC0_2e$ if each lever were pursued aggressively. It is not a forecast of what role different abatement measures and technologies will play.

EX 21: Global technical mitigation potential by 2030 of each agricultural management practice showing the impacts of each practice on each greenhouse gas.



Source: IPCC, 2007

EX 22: Emissions developments for the Agriculture sector MtCO2e per year



Source: McKinsey, Global GHG Abatement Cost Curve v2.0. Note: * Economic potential of technical measures. The curve presents an estimate of the maximum potential of all technical GHG abatement measures below €60 per tC02e if each lever was pursued aggressively. It is not a forecast of what role different abatement measures and technologies will play.

Mitigation through Offset Markets

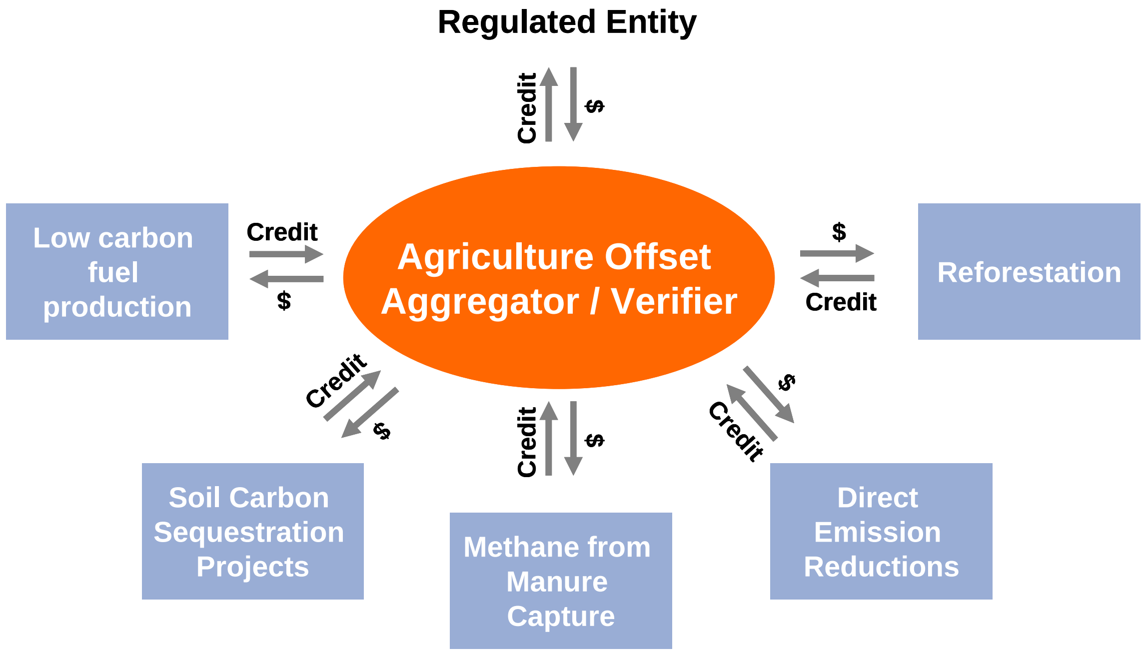
The US EPA has developed offset cost modeling in their 2005 report for the development of the US offset market (US EPA 2005). These offset market models include practices such as no till agriculture, winter cover crops and some biofuels mandates. While the science of carbon sequestration from agriculture continues to evolve, the issue of land use change as a function of crop demand will keep the biofuels aspect a critical component of the offset market, not only in the US but globally (Exhibit 23). The duration of offset contracts has also caused some criticism as farmers are used to spot markets, such as 6-12 months, whereas in the offset market farmers would need to sell carbon credits on a 5- 10 year carbon contract basis. In that time, costs of production will vary, such as planting costs, fertilizers, use of land. Agriculture and land use remain dynamic and it remains unclear if it will have a significant sink potential. Again, this reiterates the need for explicit spatial data for planning in order to properly manage and monitor not just the scientific impacts of climate change, but the management of carbon dynamics in fields. Therefore, agriculture and agricultural offset policies need to be adaptable as management systems will need to adjust with changing climatic conditions (See Exhibit 24 for how an offset market works).

EX 23: Opportunities for Agricultural Offset Markets

- Carbon offsets are reductions in greenhouse gas emissions, or for agriculture the amount of carbon that can be sequestered or stored in the ground and in biomass.
- Agricultural practices can offset or reduce greenhouse gases through no-till practices, increasing vegetative buffers and reforestation, and capturing manure methane.
- Agriculture could generate carbon credits under a cap and trade market and has been estimated as over $300 billion in the US alone.
- Provides economic mechanism to reduce deforestation and formally protect forested land.
- In the US, the Markey-Waxman Offset Provision released on March 31, 2009 proposed an economy-wide cap and trade program allowing for offset provisions. The provision established an Offsets Integrity Advisory Board that can recommend eligibility and methodologies.
- Offsets must be additional from a baseline activity, with consistent measurement, a methodology for monitoring leakage and determining any uncertainty or reversal of carbon sequestration. The details of the offset policy still need to be determined , but this potential market does offer incentives for adoption of best management practices.
- This may be extended to international offset programs and provide incentives for countries to reduce their emissions.
- Non-capped sources of emissions reductions at a lower cost.
- The existing offset markets need to be revisited in light of an emerging global carbon market.
- Proper fertilization, irrigation, and rotational grazing can increase plant productivity on pasture lands, resulting in more absorption of carbon.
- Adjusting the amount and timing of fertilizer application can reduce emissions of nitrous oxide, a fertilizer byproduct.

Source: DBCCA analysis, 2009.

EX 24: How an Offset Market works



Source: Adapted from WRI, 2008; DeAM Analysis, 2009.

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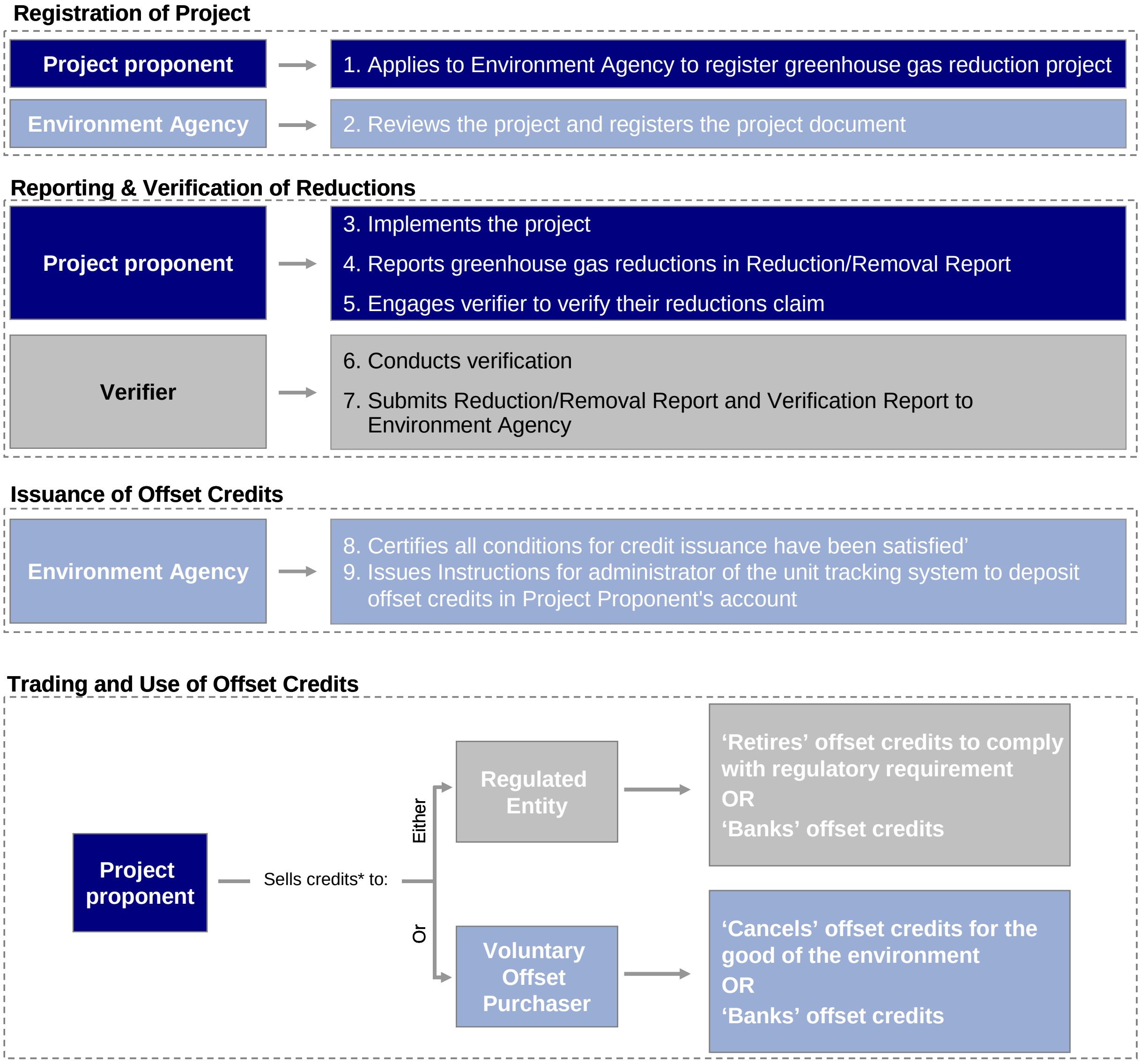


Source: Adapted from Government of Canada Offset markets, 2008; DeAM Analysis, 2009.

Adaptation

Adaptation, the adjustment of practices, processes or structures to take into account changing climatic conditions is critical for meeting the growing demand for agricultural products and is the focus of much of this report. Agricultural systems can be adversely affected to variable weather patterns. Within the context of investing in climate change, agriculture falls more under the umbrella of adaptation.

It has been demonstrated that increasing agricultural yields and better use of land are the most promising opportunities to meet the rising demand for agricultural production. The need for these lands to meet food production demand while simultaneously responding to the climate change challenge requires broad governmental support and the deployment of capital on a massive scale. It is the supply side response to the growing demand for food and more recently biofuels, that will meet the growing demand. It is necessary to have detailed knowledge of existing productivity, identify the proper uses of water for irrigation, fertilizers for croplands and other soil and agricultural management practices. Using analytical tools, we are able to understand which crops would grow best under which climatic conditions and therefore are able to be much more efficient in increasing our productivity. The key to adapting to climate change is using a dynamic planning tool that will incorporate local agro-climatic conditions to maintain productivity.

The focus of policymakers should thus be on formulating and implementing policies that promote better adaptation. In particular, incentives that promote adaptation need to be formulated and incorporated into project designs. It is also clear that policymakers should promote dynamic adaptation, as it is unlikely that there will be one solution for all time. Finally, incentives that promote adaptation policies should be incorporated into poverty reduction and other sustainable development policies that in turn will also enhance the resiliency of the agricultural sector.

EX 25A: Select Opportunities for Adaptation in Agriculture

- Portfolio diversification
- Adjusting timing of farm operations
- Changing cropping intensity
- Changes in tillage practices
- Temporary migration
- Changing crop mix
- Irrigation
- Modernization of farm operations
- Defining land use and tenure rights
- Efficient water use
- Investment promotion
- Promoting trade
- Crop Insurance
- Developing extension services
- Improving forecasting mechanisms
- Institutional strengthening and decision making structures

Source: FAO, 2008, World Bank 2006.

EX 25B: Select Opportunities for Adaptation in Agriculture

Short-Term Adaptations: Farm Responses, Temporary Migration, Insurance

Long-Term Adaptations: Changing Crop Type and Location, Development of New Technologies and Modernization, Improving Water Management, Permanent Migration of Labor

Adaptations Irrespective of the Temporal Dimension of Climate Impacts: Investment and Accumulation of Capital, Reform of Pricing Schemes, Development of Open Markets, and other Reforms, Adoption of New Technologies, Promotion of Trade, Extension Services, Diversification of Income-Earning and Employment Opportunities, Dissemination of Climate Data, Institutional Planning and Implementation.

Source: FAO, 2008, World Bank 2006.

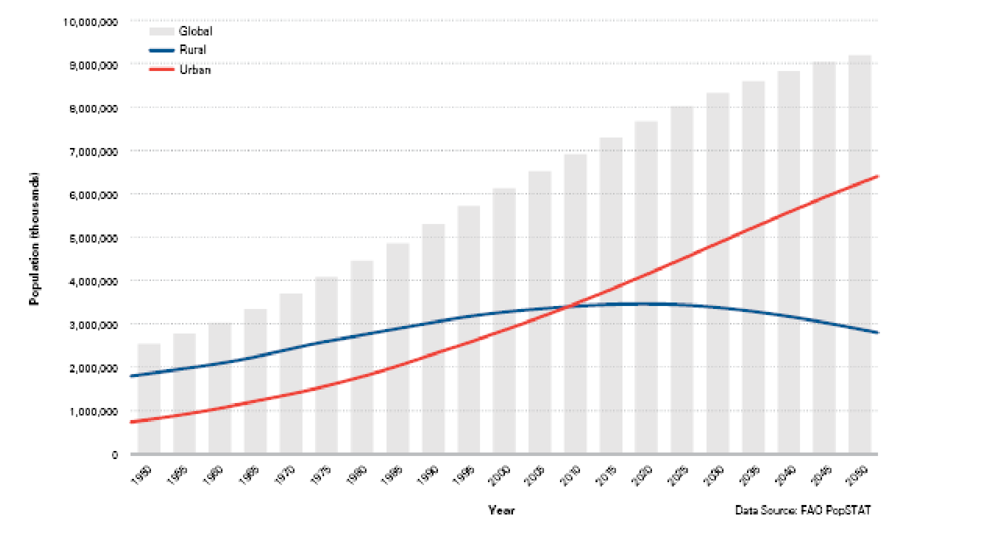
Policy makers have the opportunity to improve agricultural productivity, reduce poverty and mitigate and adapt to climate change. However, agricultural improvements must go hand-in-hand with forest-conservation policies, since agricultural intensification can lead to avoided deforestation. A low-carbon growth plan needs a regulatory and legal framework that supports forest conservation, through enforcement, land tenure, effective tax and credit policies, and policies that empower indigenous people and local communities. Favorable institutional and governance conditions need to be established that guarantee a long term stable incentive and control system for maintaining forest carbon stocks.

Demand for Food and Agricultural Production

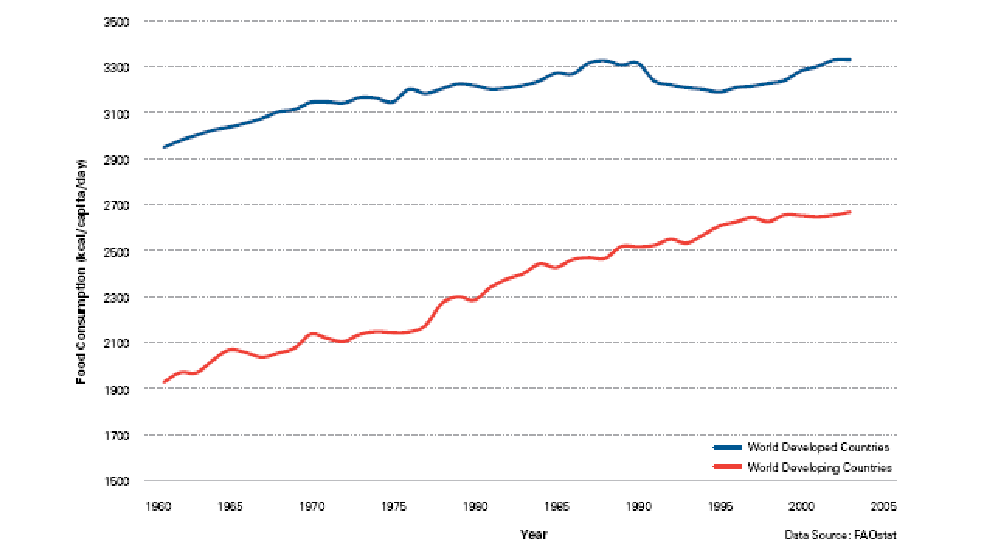
Demand for food and fuel

Several key factors influence aggregate demand for agricultural products (Exhibits 26-29). The last few decades have seen unprecedented population growth, mostly in developing countries. However, the next few decades may see a decline in global agricultural production growth to roughly 1.5 % and by 2050, the growth rate could decline to approximately 0.9 % (Alexandratos, 2006). This slow-down reflects lower global population growth (~ 1.1% per year). However, increasing per capita GDP (2.2-2.4% p.a. for developed countries and 3.6-4.0% in developing countries) and increasing dietary calorie and protein demand will continue to drive agricultural demand. The growth in world cereals output in the last 30 years has been made by a 13% increase in cultivated land and a 2.0% increase in productivity in the last 45 years, 1.3% last 20 years (cereals) (Alexandratos, 2006). Maize and rice have seen yield increases but most crops have had low yield growth rates for many years. And while the short-term demand has declined, the long-term trend is still intact, according to the recently published Agriculture Outlook by FAO (FAO, 2009).

EX 26: Global Population Trends

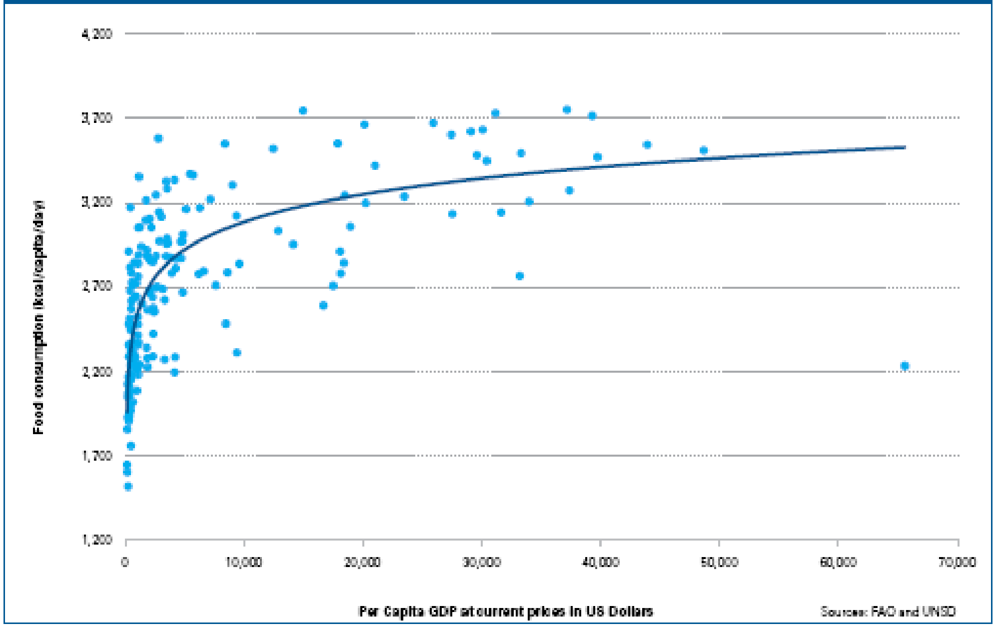


EX 27: Food Consumption in Developing and Developed Countries

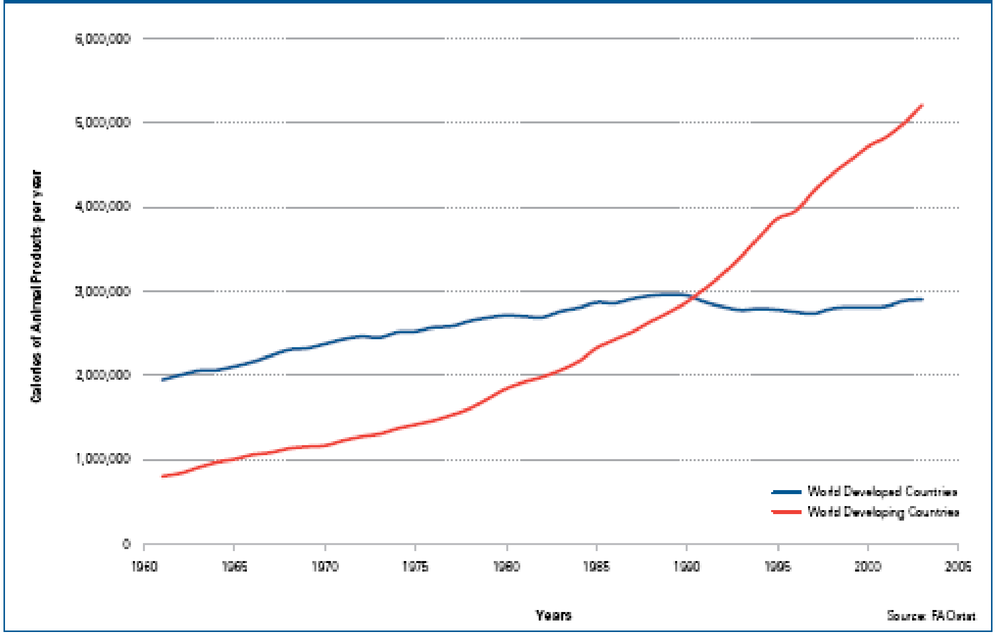


Demand for Food and Agricultural Production

EX 28: Calorie Consumption per Capita vs. GDP per Capita (2003)



EX 29: Consumption of Animal Products



Biofuels

Expanding biofuel production has and will continue to cause growth in demand for agricultural products. Biofuels have been blamed for anywhere from 2-25% of the spike in recent food price increases (Mitchell, 2008, Trostle, 2008), although many have refuted these figures. Since the price spikes of 2008, commodity and biofuel prices have both fallen, illustrating their tight correlation with the price of oil and other primary energy products.

Regardless, demand for agricultural products is expected to rise, and investments are needed to ensure continued production to meet the needs of consumers worldwide. While diversion of grains and oilseeds to ethanol and biodiesel has certainly increased since 2000, it remains a small percentage of global production relative to animal feed (Exhibits 30-31). Our aim here is to show that while biofuels currently account for only a small part of agricultural production, their continued growth will require sound strategies for choosing land for biofuel feedstock production, and aggressive development of second and third generation biofuels.

Biofuel demand, including both ethanol and biodiesel, is expected to reach volumes of 37 billion gallons by 2017, from just a handful of feedstocks (FAPRI, 2008). This is due in part to governmental mandates of biofuel production and the prospective of fuel switching for both economic and carbon policy reasons. According to Clean Edge Inc, global production with wholesale pricing of ethanol and biodiesel reached $25.4 billion in 2007 and is projected to grow to $81.1 billion by 2017. In 2007 the global biofuels market consisted of more than 13 billion gallons of ethanol and 2 billion gallons of biodiesel production worldwide. This increased in 2008 to 17 billion and 3.5 billion gallons for ethanol and biodiesel, respectively.

The growth in production of oilseeds and grains, among other commodities, has risen recently due to surging demand from the food and feed sectors. Biofuels from agricultural products have begun to play a larger role in this growth as crops are diverted to this exploding industry. Analysis of the major grain and oilseed feedstocks converted into biofuels shows growth in demand for all feedstocks by the biofuel sector. The diversion of grains and oilseeds to biofuels went from 1.2% of production in 2000 to 4.2% in 2007. The use of agricultural crops as a biofuel feedstock is a fast growing segment, but one that is still less than 5% of total agricultural production. Of these feedstocks, crops used to produce ethanol account for ~90% of the diverted agricultural products, while 10% are used in biodiesel. It is important to note that production of 1st generation biofuels generates many co-products that are used in other industry sectors. For example, bagasse from Brazilian sugarcane plants is used to power the ethanol conversion process, and dried distillers grains from corn ethanol are used as livestock feed.

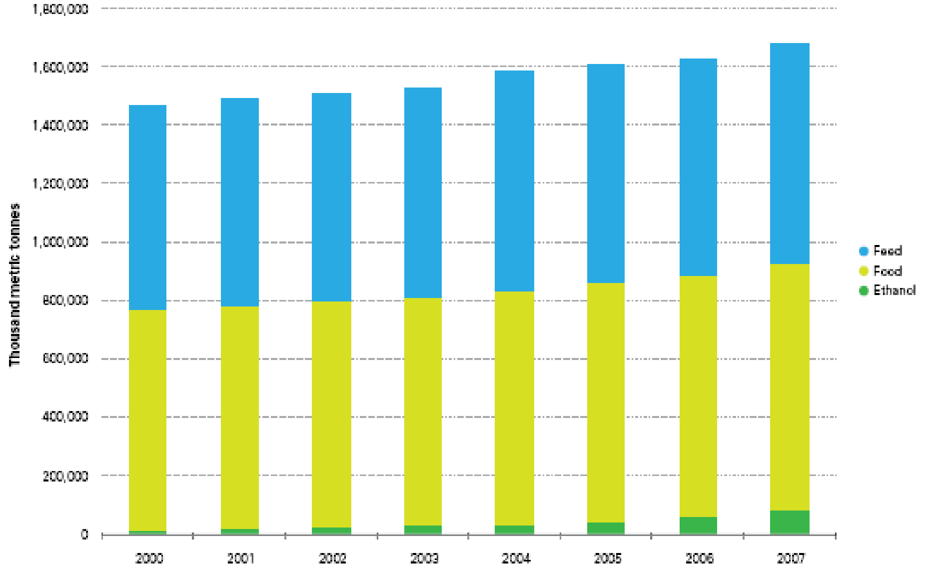
As per capita caloric consumption increases, the efficiency of each sector in providing consumable calories will be of utmost importance. The overall increase in demand puts additional pressure on our agricultural system in the short term, increasing the likelihood that marginal lands will be put into production and cause further GHG emissions and other environmental damage. Producing low-carbon fuels is a global priority, but diverting food crops for conversion into biofuels is not seen as a long-term strategy. Unless second and third generation biofuels are introduced, increasing biofuel demand will lead to further competition for land used to grow food (FAO, 2008).

EX 30: Global Distribution of Oilseeds to Food, Feed and Biodiesel

Source: SAGE

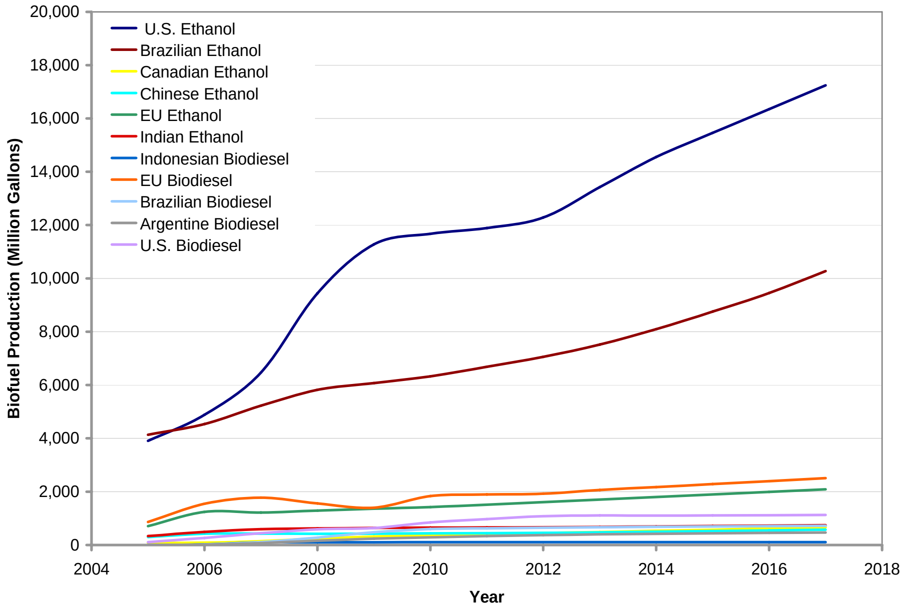
Demand for Food and Agricultural Production

EX 31: Global Distribution of Grains and Pulses to Food, Feed and Ethanol



Source: SAGE

EX 32: Global Biofuel Production



Source: FAO, 2008.

Overall, the demand for agricultural production will be driven by increasing populations, increasing growth in global per capita GDP, shifts in dietary trends, and the global rise in biofuel demand. As these factors continue to interact, commodity prices will be affected. This projection requires that our agricultural system continue to adapt to changing marketplace conditions. While there has been growth of production over the past few decades, it has not been uniform across crops or across regions. Moreover, production growth rates are projected to slow, as investments in new agricultural technology have not rivaled those of the Green Revolution. Therefore, in order to avoid a supply/demand gap, our agricultural system must respond by increasing productivity. Crops that compete with food are not sustainable and the success of the future of biofuels depends on productivity of low uses of land (i.e. algae, waste products).

Supply of Agricultural Production

Supply of food and fuel

Land Use/ Land Cover

In order to increase agricultural productivity, we need to consider both landuse and crop yields. We have seen trends in agricultural production change rapidly over the years via political and technological means, and land remains available where productivity can be increased without diminishing the vital ecosystem services that we depend on.

In order to assess properly the current and potential future cropping patterns, we analyzed global agricultural production using a geographic information system (GIS). As we conduct research into investment opportunities across the agri-business industry, a GIS can depict patterns of production, environmental attributes, management practices and other data in a spatially explicit manner. This type of analysis aids decision makers and investors in understanding the dynamics occurring on the ground, and we can use scenarios to provide insight into potential future changes.

The data used in a GIS is typically derived from censuses, aerial photographs, satellite imagery and computer model simulations. Once several map-layers of various attributes are generated, relationships between attributes can be analyzed, including the current distribution of areas that practice multiple cropping and those areas that can sustain the practice.

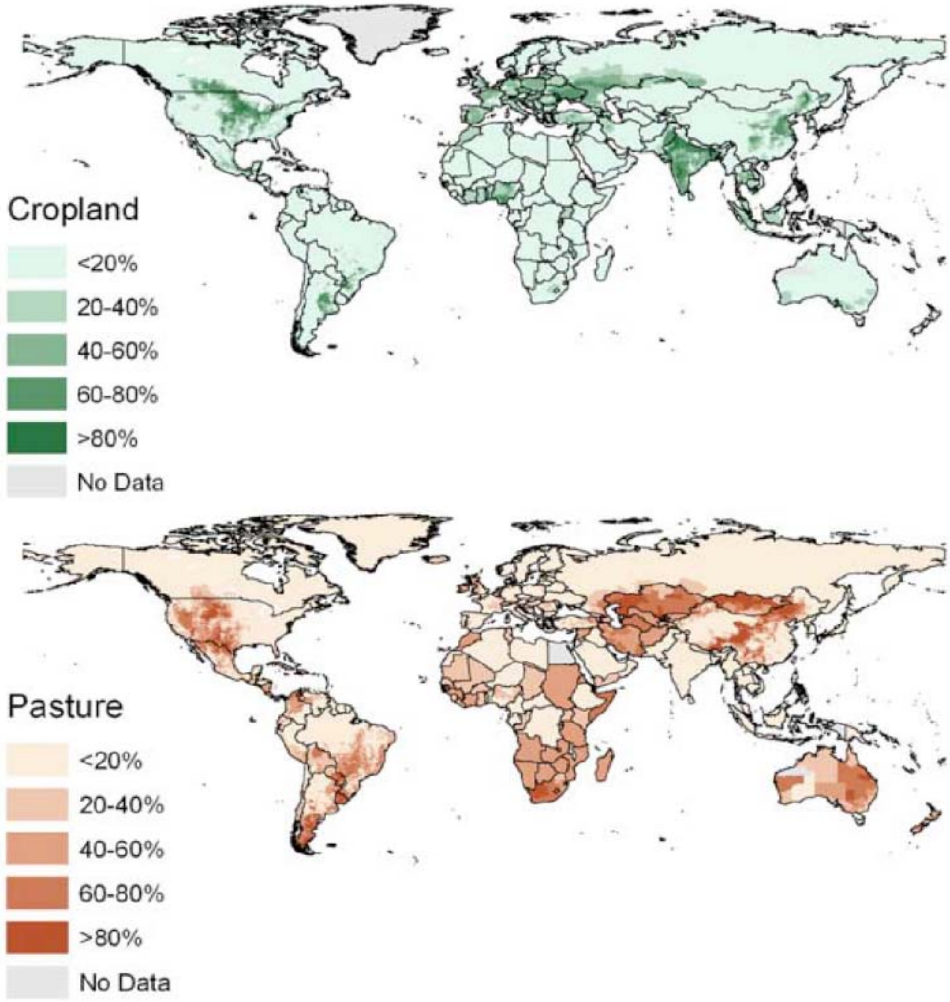
If we are to manage global agriculture sustainably, we need tools and data to make informed decisions. Currently, satellite imagery is used to identify classes of land cover, such as urban area, forest or cropland, based on interpretation of imagery and/or ground reconnaissance. While satellite imagery can tell us what areas are used for agriculture, they cannot say what crop or how much of it is grown each year. Data of this type are available at various spatial scales, from the county scale to national-level statistics that are compiled by the United Nation's Food and Agriculture Organization (FAO). Work is ongoing to merge these two types of data and put the combined product in the hands of analysts and decision makers.

The Nelson Institute Center for Sustainability and the Global Environment (SAGE) at the University of Wisconsin, Madison has been working for the past decade to describe the global agricultural system, both its historic evolution and its current extent. The latest data products released by SAGE (described in detail in Ramankutty et al 2008 and Monfreda et al 2008, also see www.sage.wisc.edu) present the global extent of croplands and pastures in a spatially explicit manner. While FAO data provides extremely valuable documentation of the national-level distribution of crops, the fusion of FAO statistical data with satellite imagery of the Earth allows for a much richer analysis.

Supply of Agricultural Production

There are 15 million sq. km of croplands and 28 million sq km. of pastures, which corresponds to 34% of the Earth's ice-free land surface. The intensity of the color corresponds to the percentage of cropland or pasture in a given area.

EX 33: The distribution of croplands and pastures around the year 2000, as described by Ramankutty et al. 2008.



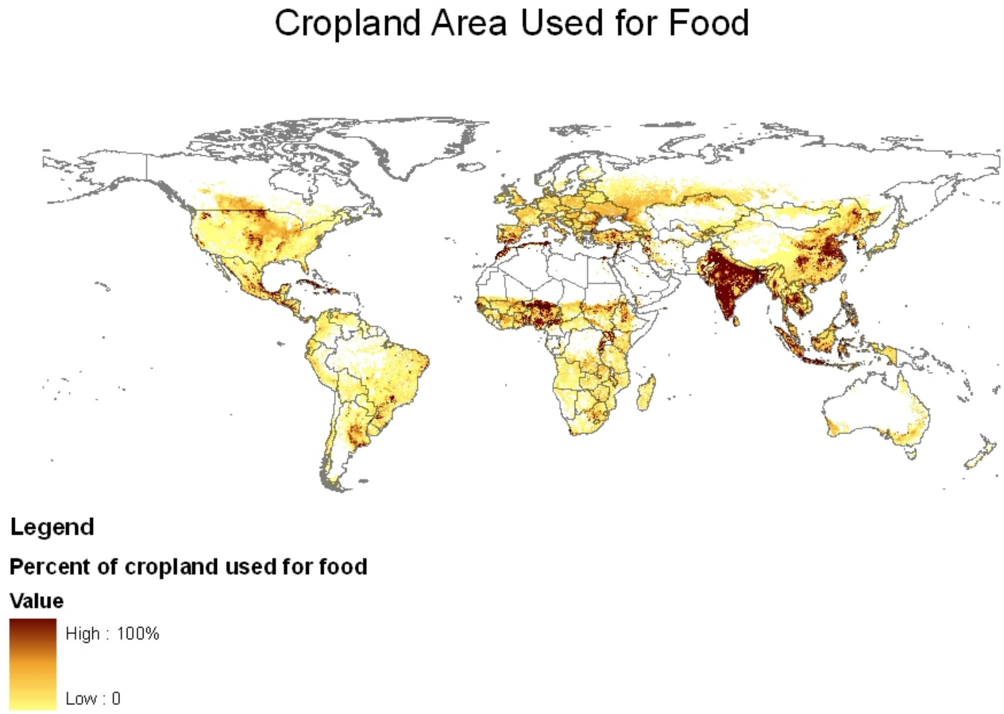
Source: Ramankutty 2008

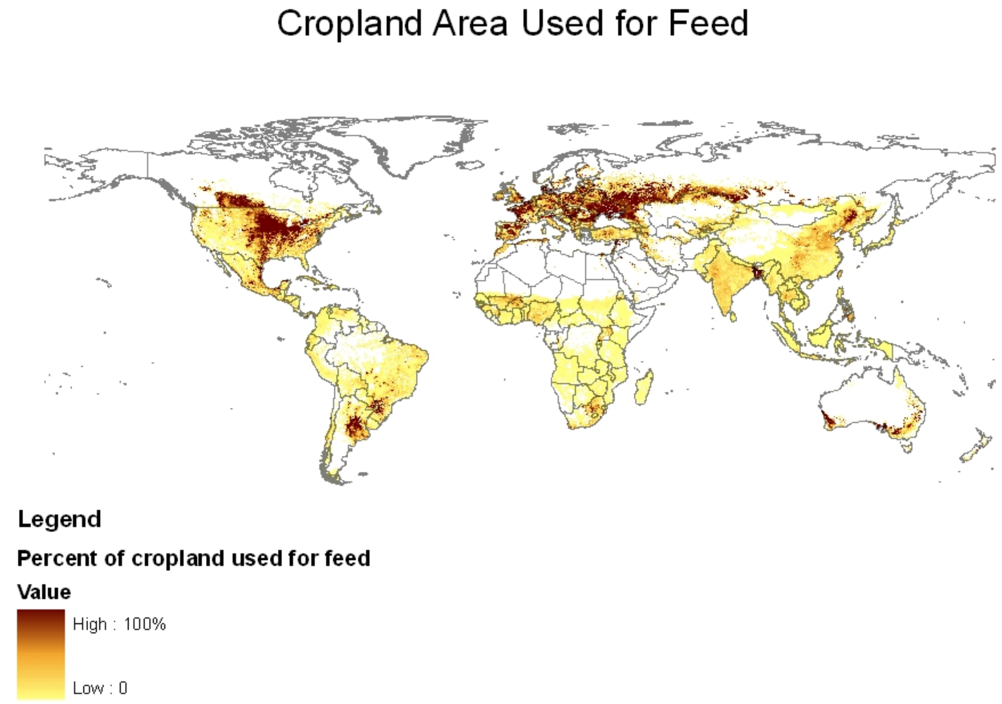
Not only is the location of croplands described by this analysis, but also the distribution and yield of over 175 crops that are used for food, feed, fiber and fuel. When identifying future opportunities in agriculture, it is crucial not only to know "how much," but also "where" these agricultural products grow. The distribution of crops and their yields depend on many factors that range from climate to management to social and political factors. When assessing opportunities to increase the agricultural output in order to satisfy our caloric needs, all of these factors must be taken into account. Ongoing research is delving into these complex and important questions, and some preliminary analyses will be presented here.

It would be unwieldy to present the distribution and productivity of all 175 crops, but the data can be aggregated to show the distribution of crops that are consumed directly by people versus those used as animal feed. Globally, 58% of croplands are used for food crops, while 34% of croplands are used for feed crops. This breakdown only includes land for croplands and not for pastures (which are used only for animal production). There are stark geographic differences in the distribution of food and feed crops. The distribution of agricultural land, broken down into areas used for food, feed and pasture, can be further broken down by region. A large segment of North American and European agricultural production is devoted to feed crops, while the majority of areas in sub-Saharan Africa and the Indian subcontinent are used to produce food directly consumed by people.

The percentage of each grid cell dedicated to the production of each cropping system is depicted.

EX 34: The amount of the land surface committed to the production of food and the production of animal feed.



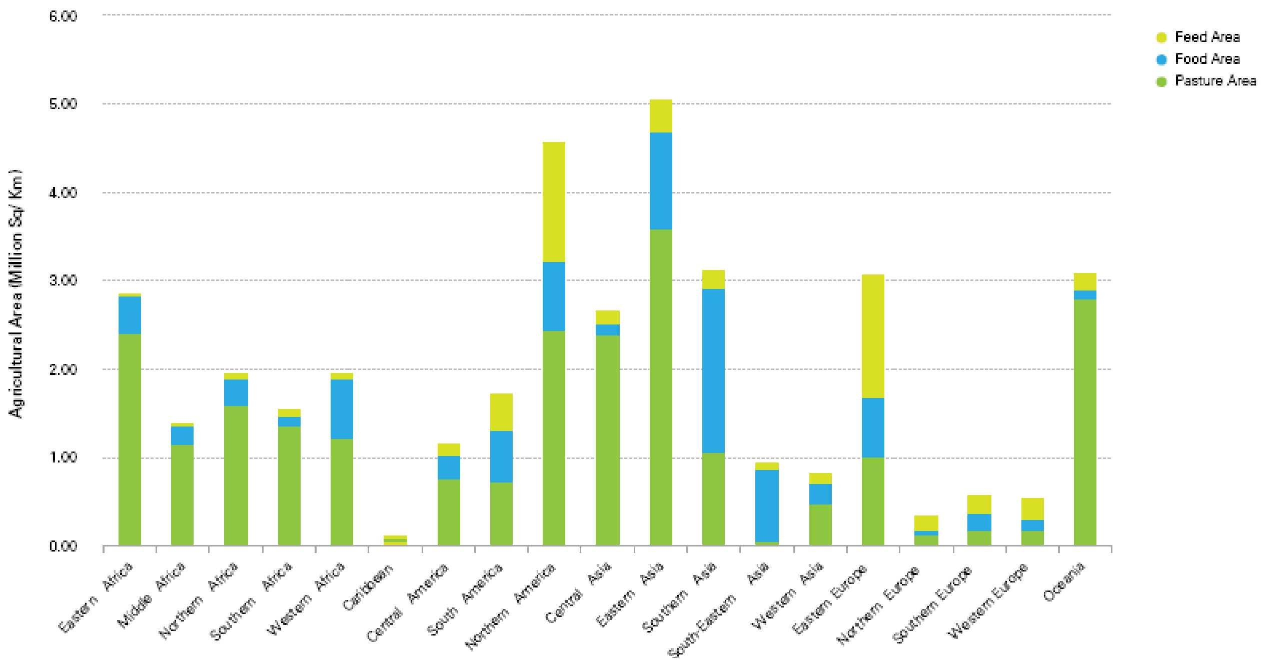


Source: SAGE data, 2009

Supply of Agricultural Production

Agricultural land area is used for growing food for people, growing feed crops for livestock, and for pasture. The pattern of this land use is highly variable across the globe and is a function of climate and soil characteristics, as well as technology and management practices.

EX 35: Global agriculture area and use, by region



Source: SAGE data, 2009.

The majority of the analyses presented here consider only the possibility of increasing production on lands currently used to grow crops or to pasture animals. Using complementary datasets to show other land uses (i.e. forests, urban areas) and their ecological integrity (degradation status, carbon sequestration potential) it is possible to identify lands not currently part of the agricultural system that could be converted with minimal environmental cost. In general, these lands are highly productive tropical pastures, abandoned agricultural lands, or degraded lands available for rehabilitation. While extensification is possible, intensification of land currently in production is also possible through increasing yields and multiple cropping. After the widespread food price spikes of 2007-2008, it seems likely that policy-makers will increasingly heed the "food side" of the food versus fuel debate, and strive to prevent biofuels production on land needed to grow food for human consumption.

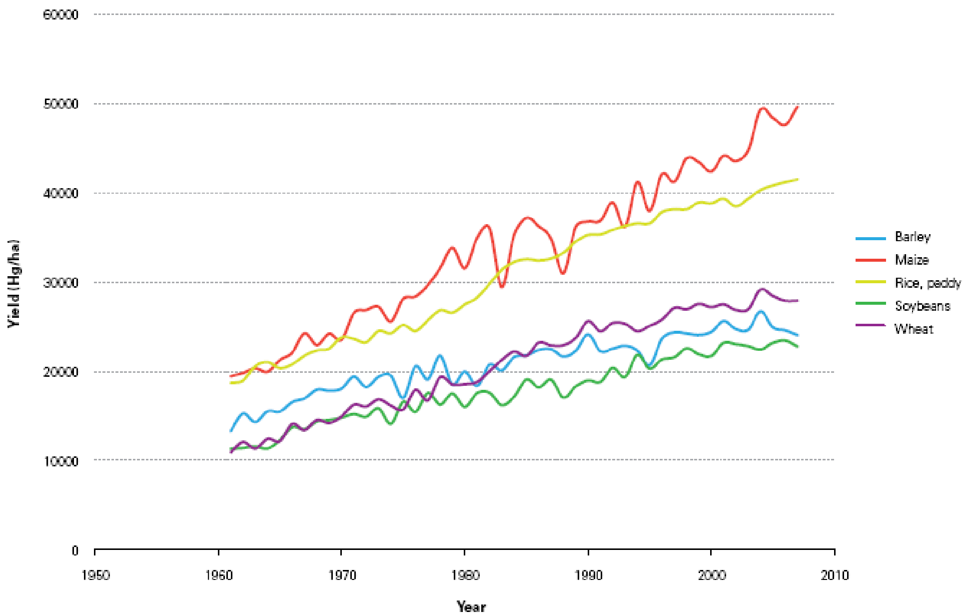
It is important to note that there is no "silver bullet" to increasing global agricultural production, only "silver buckshot" where a diverse mix of management, technology and foresight are applied to solving one of the greatest challenges we face in the next century. As we enter an era with more mouths to feed with less land per person, while needing to maintain the integrity of the natural environment, spatially explicit and detailed data are invaluable in guiding the decision making process.

Yield- With a focus on the Top 5 Crops

Current production of the major food, feed, and fuel crops has supported our growing populations and our growing demand for protein and biofuels. However, there is concern that we will not have enough land and productivity will not be high enough to meet our needs in the future. Production of agricultural commodities is driven by two factors: harvested area and yield. Yields can be highly variable from the field scale to the regional level. Maximum theoretical yields are very difficult to obtain and yields usually stagnate around 80% of their potential maximum (Cassman et al. 2003). There are myriad factors that can decrease yields, such as genotype, non-optimal solar radiation, temperature, plant population, water deficiency, nutrient deficiency or imbalance, diseases, insect pests, and weed competition (Cassman et al, 2003).

Yields have generally been increasing for the last several decades, but high rates of yield growth have given way to smaller increments as yield ceilings have been reached on an increasing proportion of agricultural lands. An example of this is rice in Southeast Asia. Rice paddies saw tremendous yield gains from 1960 to 1990, but the rate at which yields are growing in the major rice producing countries has slowed in the last two decades. Not only has the rate of yield growth slowed over time, but the geographic distribution of yields has also changed.

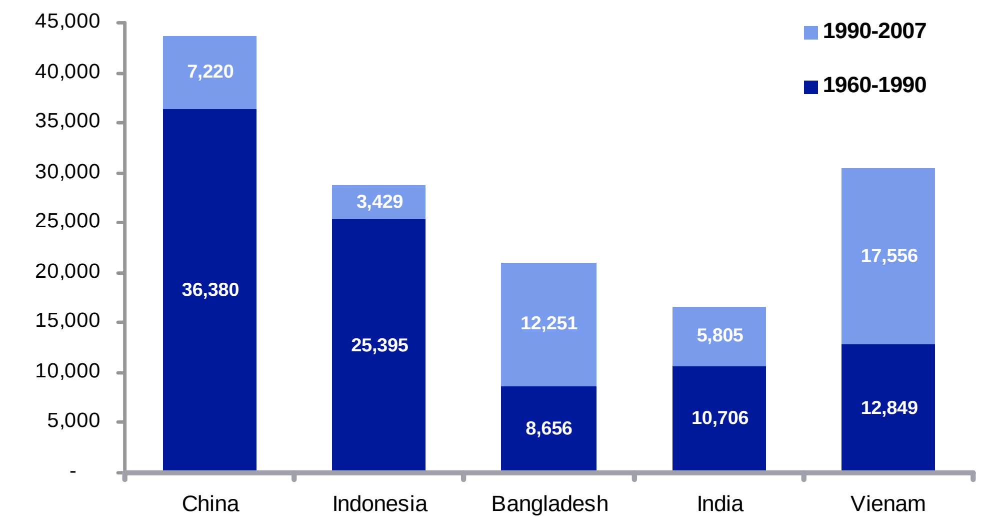
EX 36: Changes in Yield for Major Crops



Source: FAO Stat.

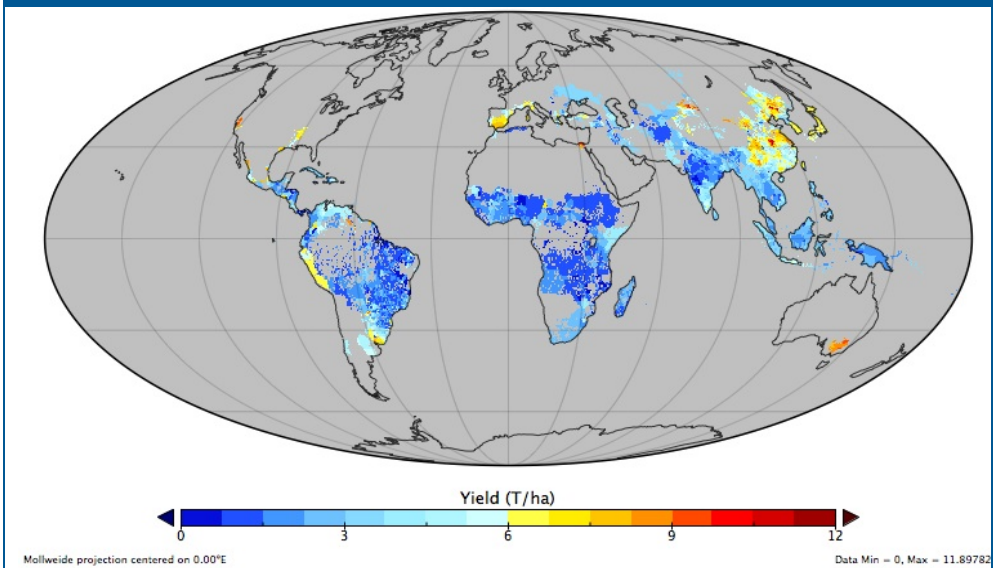
Note the differences and 1990-2007 in Exhibit 37. In China, Indonesia and India, the majority of the gains in yield occurred between 1960 and 2007. These five countries are the top producers of rice worldwide. Yields have increased considerably since 1960, but increases have slowed recently (FAOSTAT, 2008).

EX 37: Changes in Rice Yield (1960-1990, 1990-2007)



Source: FAO Stat, 2008.

EX 38: Rice Yield

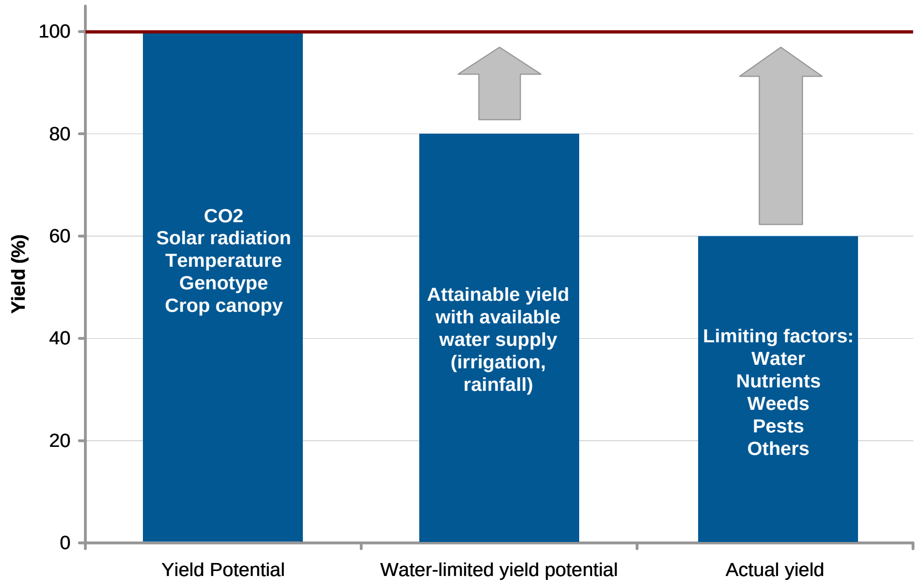


Source: Monfreda et al. 2008.

Yield Gap

Our current production estimates show that we are producing 570, 600, 590, and 165 million tonnes per year of wheat, corn, rice and soybeans, respectively. The FAO estimates that in order to meet demand for 2030 and 2050, production will need to grow substantially. In order to close this gap between current production and demand by 2050, we need to increase current production by roughly 50%, even though by some estimates, the growth rate of some major agricultural commodity yields will flatten out by 2017. However, we have seen recent increases in production of key crops such as rice (in China), and most of the world maintains great potential for yield improvement that can help to close this gap.

EX 39: Conceptual Framework of the Yield Gap



Source: Cassman et al. 2003.

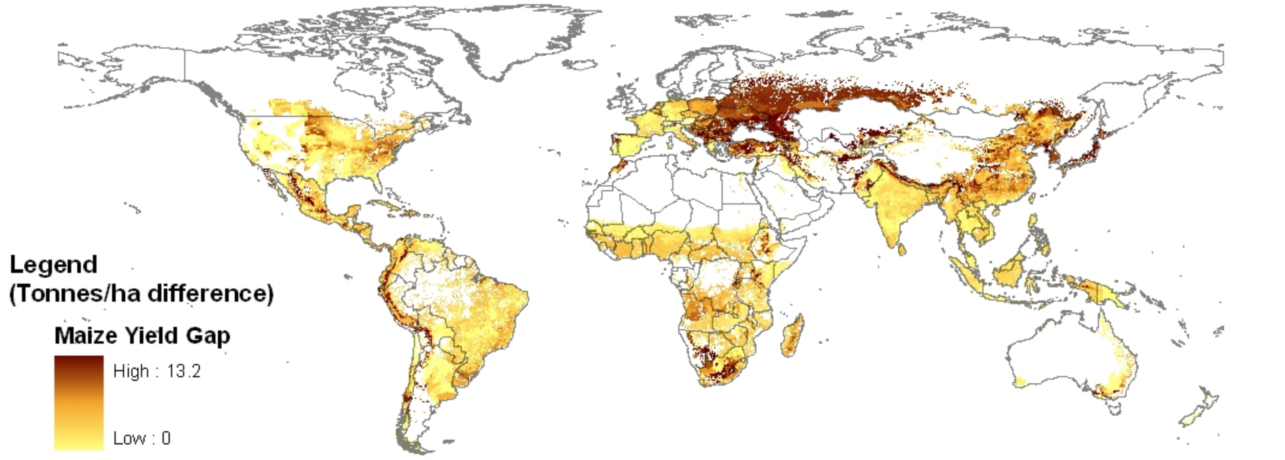
Given the environmental risks (e.g. erosion, reduced water quality, CO_2 emission) of expanding agriculture onto marginal lands, we first concentrate on increasing yields on currently cropped land. The capacity of currently cropped lands to increase productivity needs to be assessed in order to find the best opportunities for growth. Based on the Monfreda et al. (2008) data, it is possible to calculate the current range of yields for each crop. Yields should be similar between locations with similar climate, but in most cases they are not, due to differences in management (irrigation, fertilization, mechanization, seed technology, etc.).

The range of yields for croplands with similar climates can be grouped together for analysis. The average and maximum yields of a crop can be computed and compared across the growing region. The "production gap" can then be calculated for each climatic region to quantify the difference between the higher producing regions and the lower producing regions (Johnston *et al.,* 2009, Licker *et al*. (submitted)). Regions can then be identified that are most likely to be able to close the production gap with appropriate technology and with minimal environmental constraints. This analysis differs from previous production gap analyses by using actual yield data as a constraint for future production, not theoretical maximum yields which are rarely achieved (See Conceptual Framework of the Yield gap (Exhibit 39).

Using the spatially explicit analytical maps, we estimate production gaps for regions of maize, soybeans, rice, wheat and sugar cane, respectively (Exhibit 40 shown as an example). We calculate the production gap between current production and 90% of maximum production for areas with a similar climate (Exhibit 41). Comparing current production with a 90% maximum production projection for a given crop in a given region, aggregated globally, we see our production system falling behind the growing demand for 2030 and 2050 (Exhibit 42).

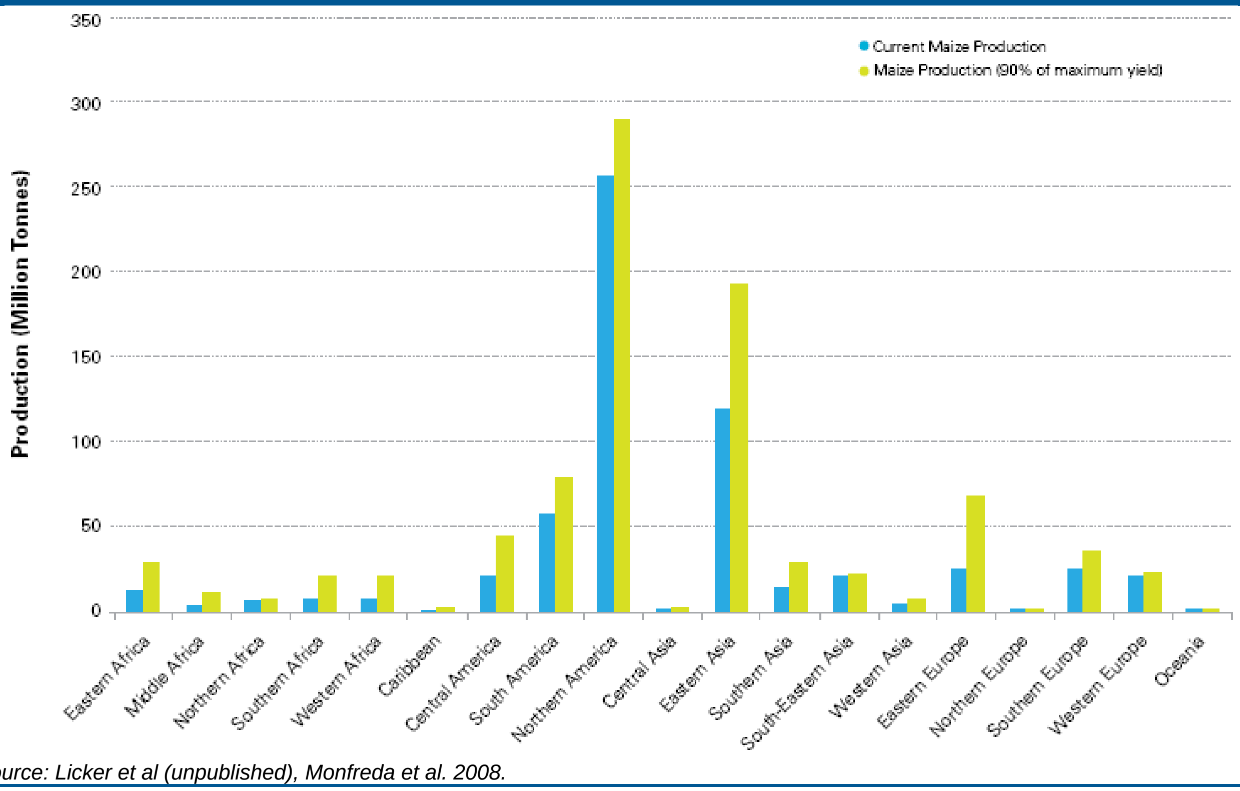
Supply of Agricultural Production

EX 40: Production gap between current production and 90% of maximum production – Maize



Source: Licker et al. Submitted

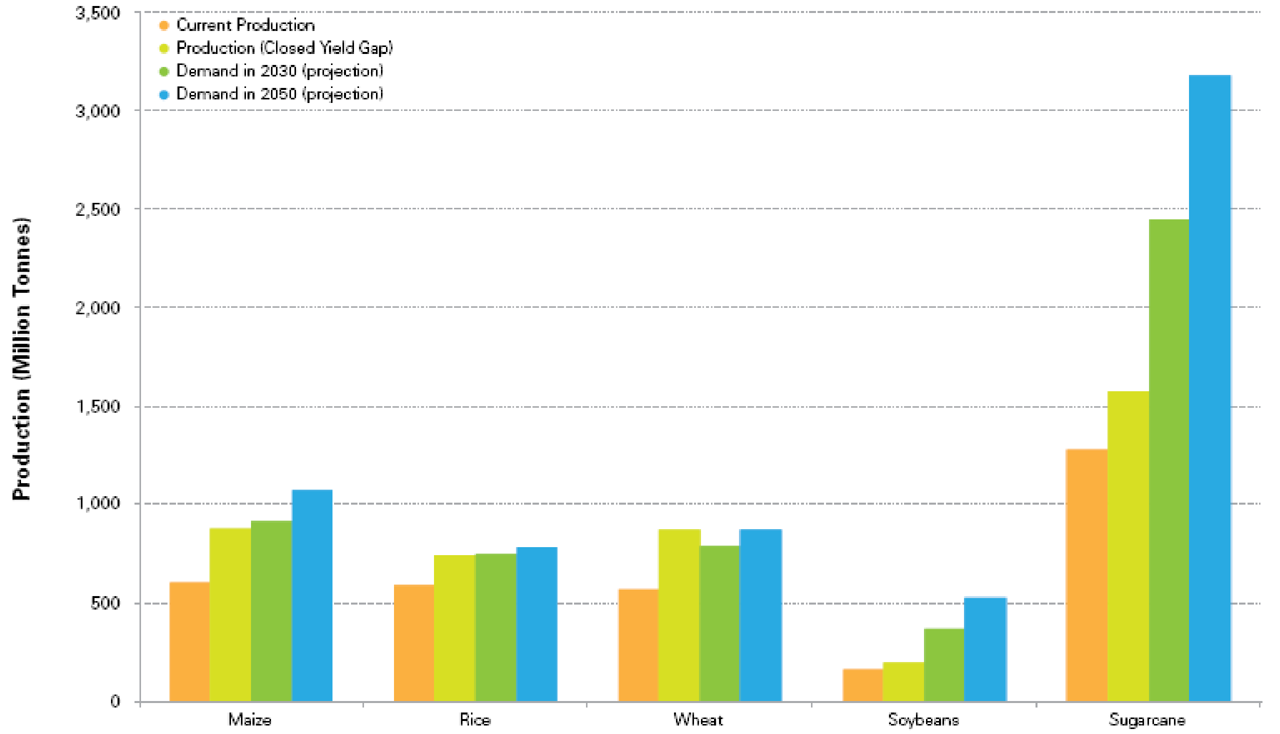
EX 41: Current Production and Potential Production from Closing Production Gap – Maize



Source: Licker et al (unpublished), Monfreda et al. 2008.

Supply of Agricultural Production

EX 42: Supply and Demand of Major Food Crops (Includes estimate for First Generation Biofuels)



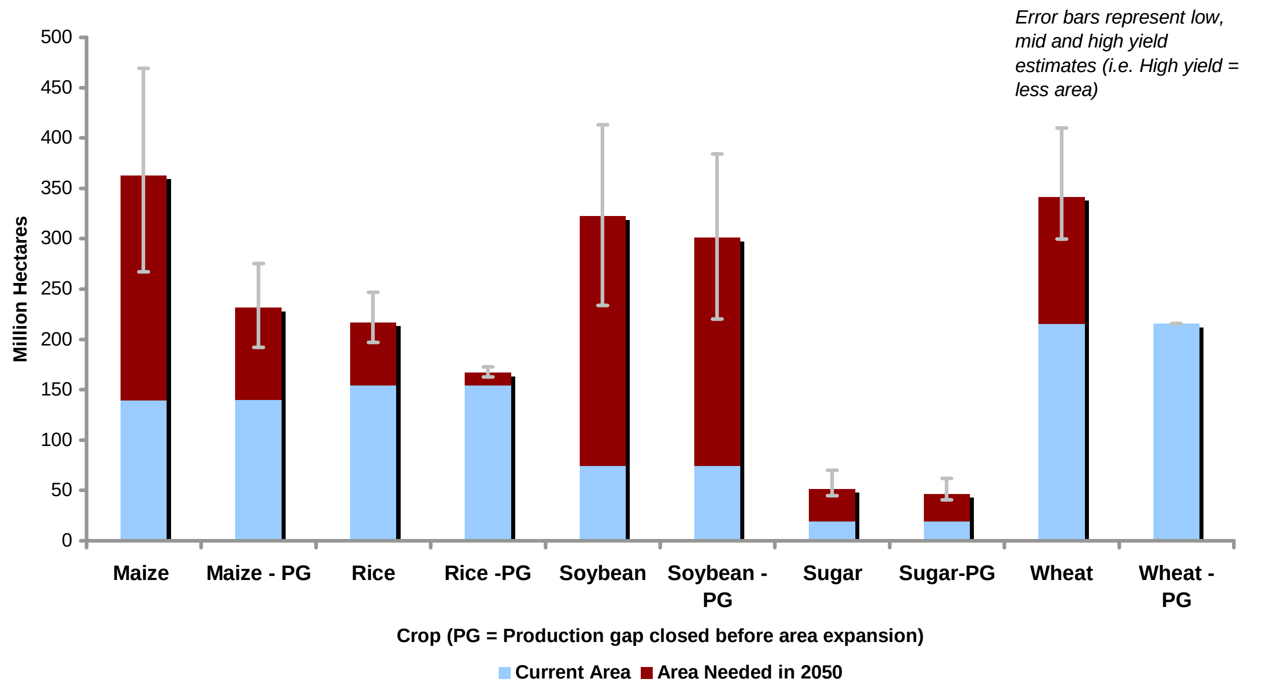
Source: SAGE, FAO Stat, World Ag to 2050.

In order to meet future food demand, crop yields and agricultural area will need to be increased. If all yields for maize, rice, wheat, soybeans and sugarcane were brought up to 90% of current maximum yields, production would satisfy demand for rice and wheat for 2030, but closing the production gap would be insufficient to meet demand in 2050. Closing the production gap for lands currently in production can be accomplished through changes in management and technology from the plant to field scale. Additional sources of land should be chosen in areas where land conversion will have minimal environmental impacts.

Raising productivity to the 90% maximum yield is no small feat and requires increased investment to develop technologies and methodologies to close the gap in an environmentally sustainable manner. While there is ample opportunity to increase productivity in many parts of the world, a clear pattern has emerged for closing production gaps in Eastern Asia for maize, rice, soy and wheat, whereas regions in Africa have the opportunity to raise productivity for soy, sugar cane and rice. As we will discuss later, switching land use and expanding land supply are going to be important elements of the solution.

Supply of Agricultural Production

EX 43: Area needed to meet demand for major commodities in 2050



Source: FAO, SAGE, 2009.

Increases in yield and area will be required to meet the demand for major food commodities in 2050. While yields vary tremendously across the globe, it is possible to provide a range of estimates of future land area required for crops. Closing the production gaps on currently used cropped lands greatly reduces the area needed for future production.

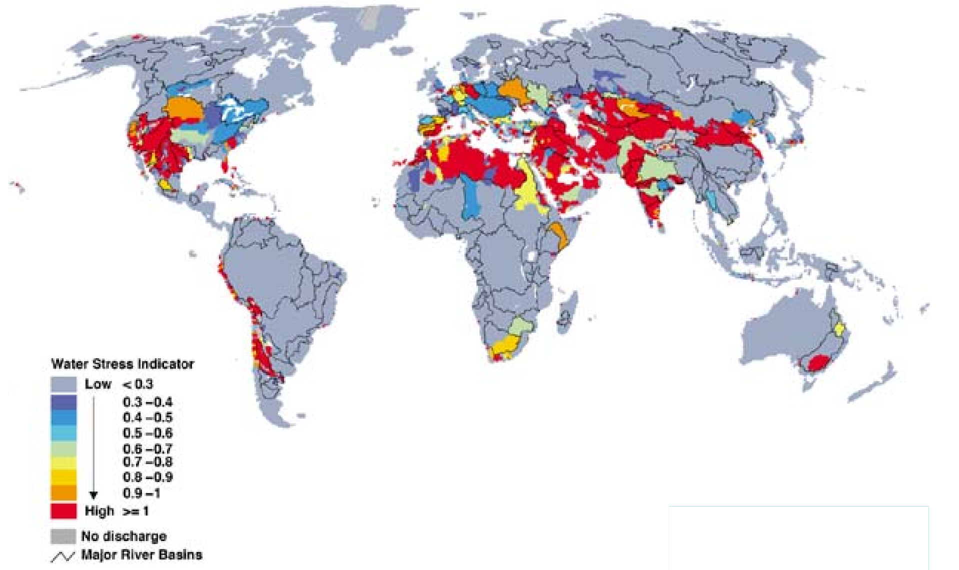
The area needed to meet demand for major crop commodities is shown above. In the two cases, a reduced amount of area is needed when the yield gap is closed before expanding to other lands. The largest difference in future land needed, given current consumption patterns, is maize, while sugar cane requires the least amount of additional land. The error bars represent the range of potential yields of the expanded land, where higher yields will require less additional land (Exhibit 43).

Constraints

While we propose to close the production gap using land use decision-making systems and other tools, several constraints to raising agricultural productivity exist. Environmental problems arising from misuse of chemical fertilizers, irrigation and machinery can cause land degradation and irreversible ecosystem damages such as loss of genetic diversity. Social problems arising from ill-defined property rights and urbanization limit the potential for sustainable agricultural expansion. In addition, as CO_2 is poised to emerge as a globally regulated greenhouse gas, the “carbon debt” of any land-use switching must be considered. Also, while irrigation can improve productivity, this may be infeasible or become highly regulated in water stressed zones, as illustrated in the Millennium Ecosystem Assessment’s scenarios of water stress across the globe (See Exhibit 44).

Supply of Agricultural Production

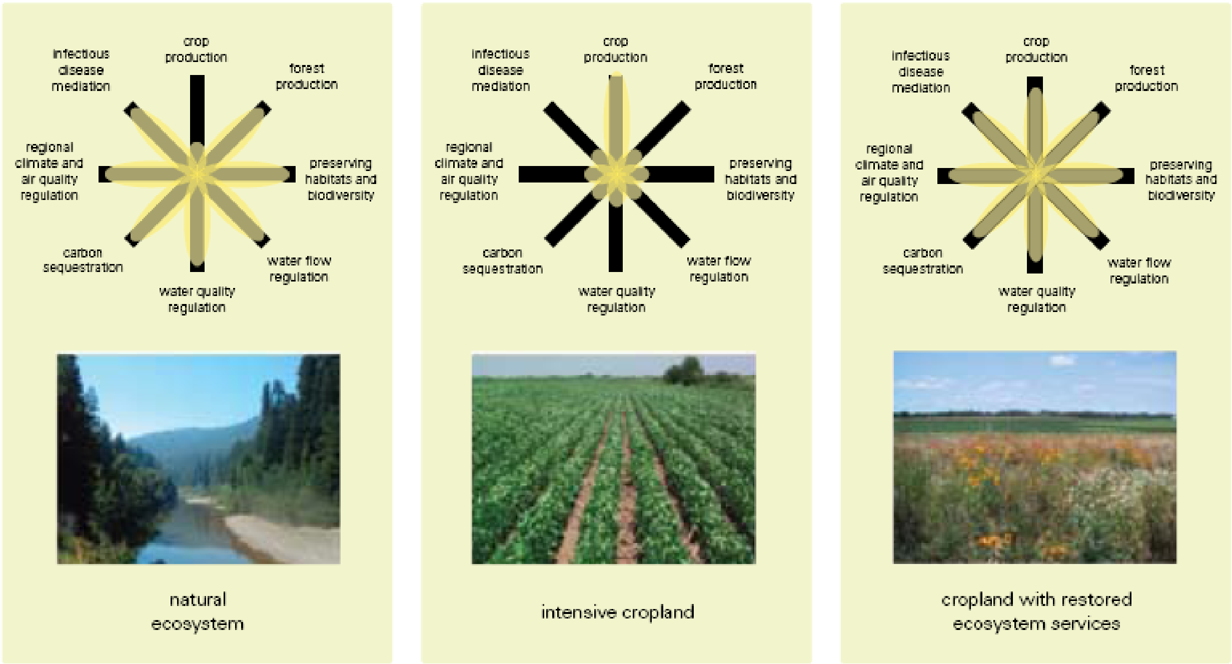
EX 44: Global Water Stress by basin



Source: World Resources Institute, 2008

Finally, while we do not explicitly treat food or land prices in this analysis, clearly these factors are critical to the emerging agricultural system. With each agricultural land-use decision, factors beyond increased crop production must be weighed. Foley et al. (2005) present a conceptual framework for assessing these trade-offs by comparing natural ecosystems, intensive croplands, and a hybrid system of both natural and cropped lands (Exhibit 45). The ability for each landscape to provide vital ecosystem services varies greatly, and with future increases in agricultural production, the full portfolio of ecosystem services will need to be considered with each decision made (See Also Box 3).

EX 45: Portfolio of services provided by various ecosystems (natural, intensive cropland, and restored cropland)

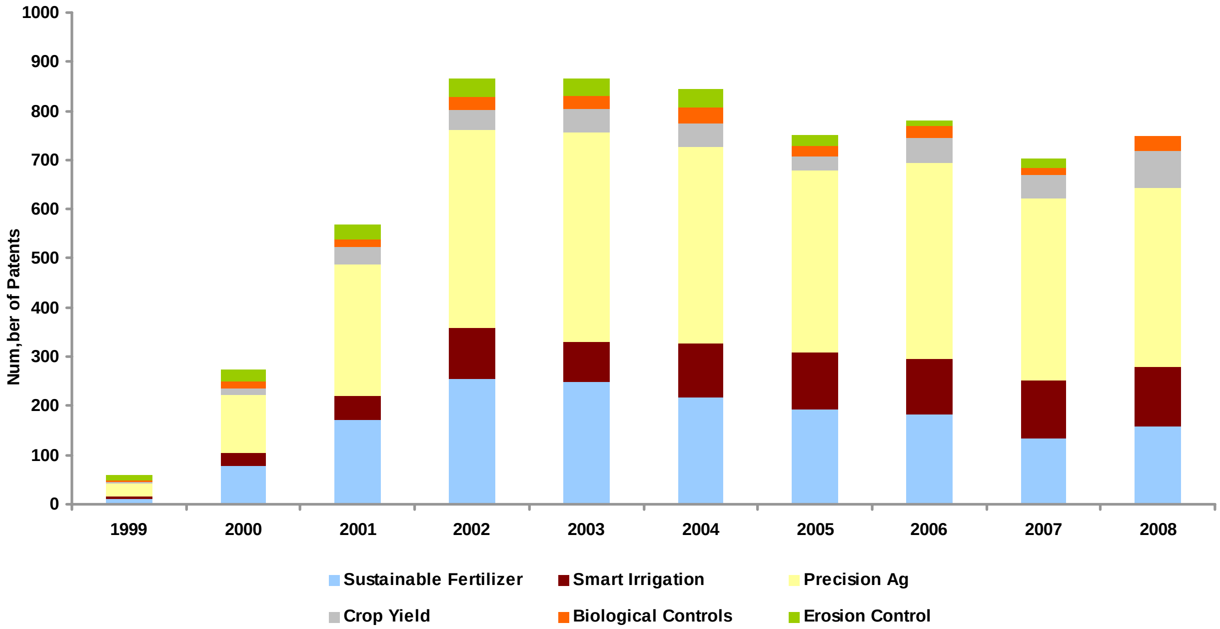


Source: Foley et al. 2005.

Investment Activity in Agriculture

The major industry trends expected to drive agricultural growth over the coming decades include the creation of drought resistant crops, increased nitrogen utilization, and higher yields for food/fuel crops. Advanced management technologies and farm commercialization will also address the productivity gap. With proper deployment of capital, technology, management and education, growth in productivity can be increased. Each area has seen substantial activity in technological development over the past ten years, as evidenced by the increase in patent filing and publication worldwide (Exhibit 46). Commercializing agricultural production across the globe will require tremendous investment into the sector. In this section, we will outline the development of various supply-side responses that can close the production gap.

EX 46: Patent Filing and Publication Velocity

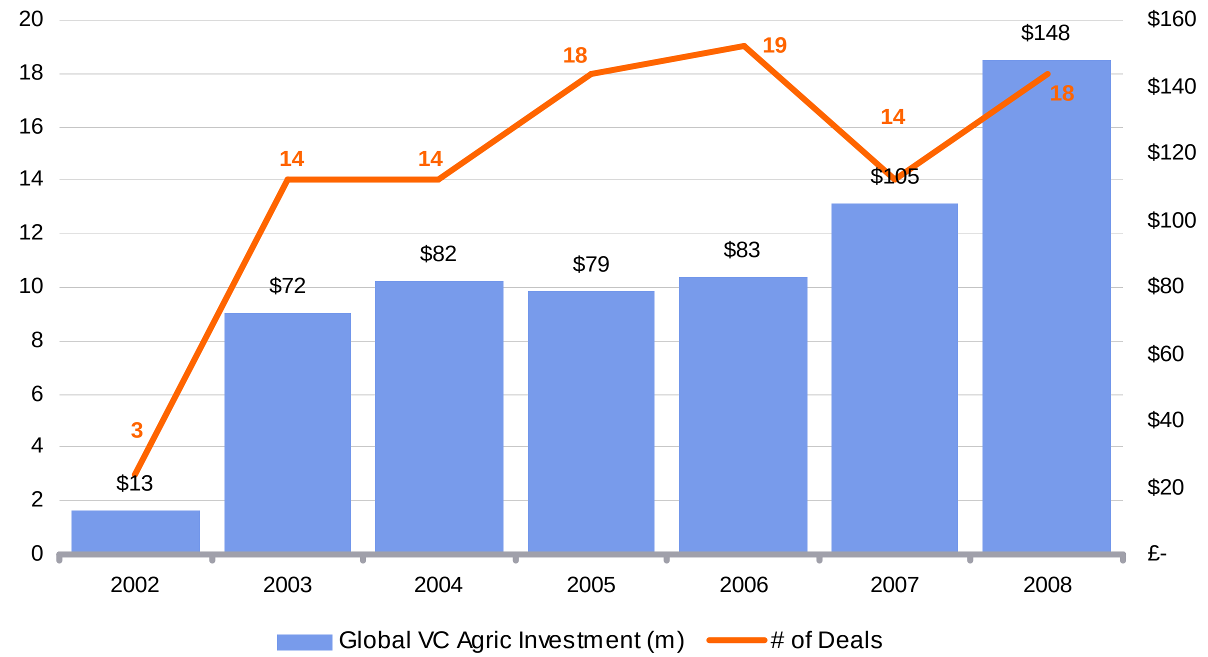


Source: IP Checkups, 2009.

Venture capital and private equity Investors have been active in the sector. Many of the advances have been in biotech crops and in biofuels (Exhibits 47, 48, and 49). While these investments have been increasing in recent years, they are still very minor in the scope of what is needed. Additional funding priorities are listed in later sections of this paper, however, the emphasis on productivity will be paramount going forward.

Closing the Production Gap

EX 47: Global VC investment in agricultural technologies



Source: CleantechGroup, 2009

EX 48: Select Investment Activities in Agriculture Technologies

<u>Recent Deals in Agricultural Technologies</u>

- Producer of organic food and other food processing services.
- Developer of natural organic fungicides and insecticides.
- Developer of improved plants that require less resources to grow.
- Developer of innovative plant technologies that optimize crop performance and productivity.
- Developer of biotechnology to improve plants to resist diseases and pests while boosting yields.
- Developer of synthetic biology technology to increase agricultural yield.
- Developer of natural weed, pest, and disease management products.
- Research and Development company specializing in detection of pathogens in food.
- Developer of a precision pest control distribution system based on naturally electrostatic palm wax powder.
- Provider of software to service growers in managing irrigation and crop growth.

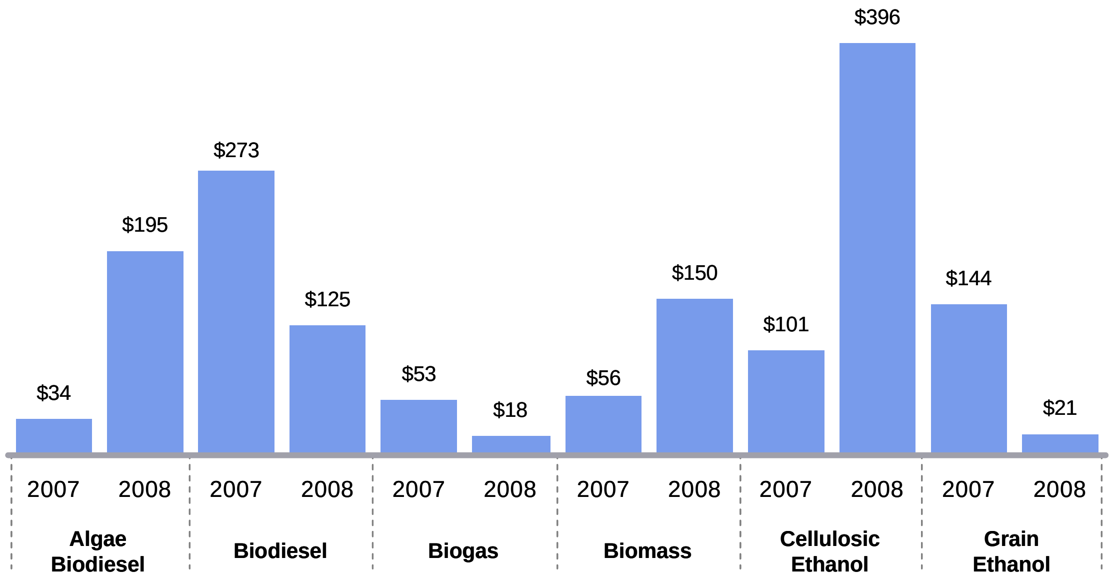
<u>Recent Deals in Biofuel Technologies</u>

- Developer of cellulosic ethanol conversion facilities that process waste biomass.
- Developer of next generation biofuels based on metabolic engineering.
- Producer of biodiesel using aquatic microbes and a process that does not require sunlight.
- Developer of a process for converting biosolids such as sewage sludge into a high-grade renewable fuel.
- Developer of microorganisms and bioreactor technology for processing biorefuse into ethanol.
- Developer and processor of non-edible bio-energy feedstock for dry wasteland areas.
- Developer of a cellulosic ethanol conversion process using agricultural waste and synthetic biology.
- Developer of genetically engineered ethanol-producing bacteria for bioprocessing of cellulosic feedstocks.

Source: Cleantech Group, 2009

Closing the Production Gap

EX 49: Investment in biofuels by technology



Source: CleantechGroup, 2009

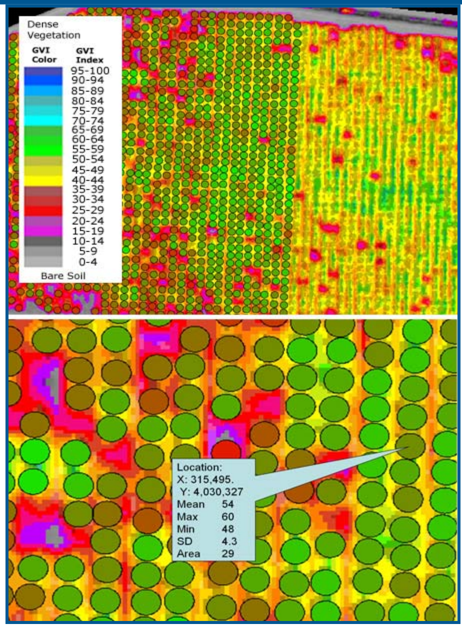
Farm Inputs

Again, the major trends expected to drive agricultural growth over the coming decades include development of drought-resistant crops, higher-yielding crops, and increased nitrogen utilization. Relative prices will impact farming tools and techniques, especially if commodity prices remain volatile. Likewise, investment in the sector will carry a certain level of risk for investors, as well as for farmers and agri-business. While the pressure to bring more land into production may grow, farmers should first use inputs more efficiently to raise productivity levels. This is a strategic area for governmental policy.

Agricultural Information Technology

The ability to measure, monitor, and verify components of the agricultural ecosystem will play an important role in the future of food production. Emerging markets for carbon, nutrients and water will need accurate data on the flows of these commodities across the agricultural landscape. Both on-farm and remote monitoring systems, that track crop productivity and constantly changing environmental variables, will need to be developed and integrated into the agribusiness economy. One way to get a grasp on our planetary goods and services is by leveraging the constellation of satellites already orbiting Earth. Global Positioning Systems (GPS) have become more common in developed agricultural economies and are designed to help minimize costs, maximize yields and enable farmers to apply inputs only where they are needed. Using GPS in conjunction with specialized satellite imagery can further the efficiency gains in crop production. While satellites are very good at detecting large scale changes, on-the-ground sensors can easily monitor changes to the farm ecosystem on a smaller scale. A global real-time distributed wireless network of sensors that monitors

EX 50: Precision Agriculture



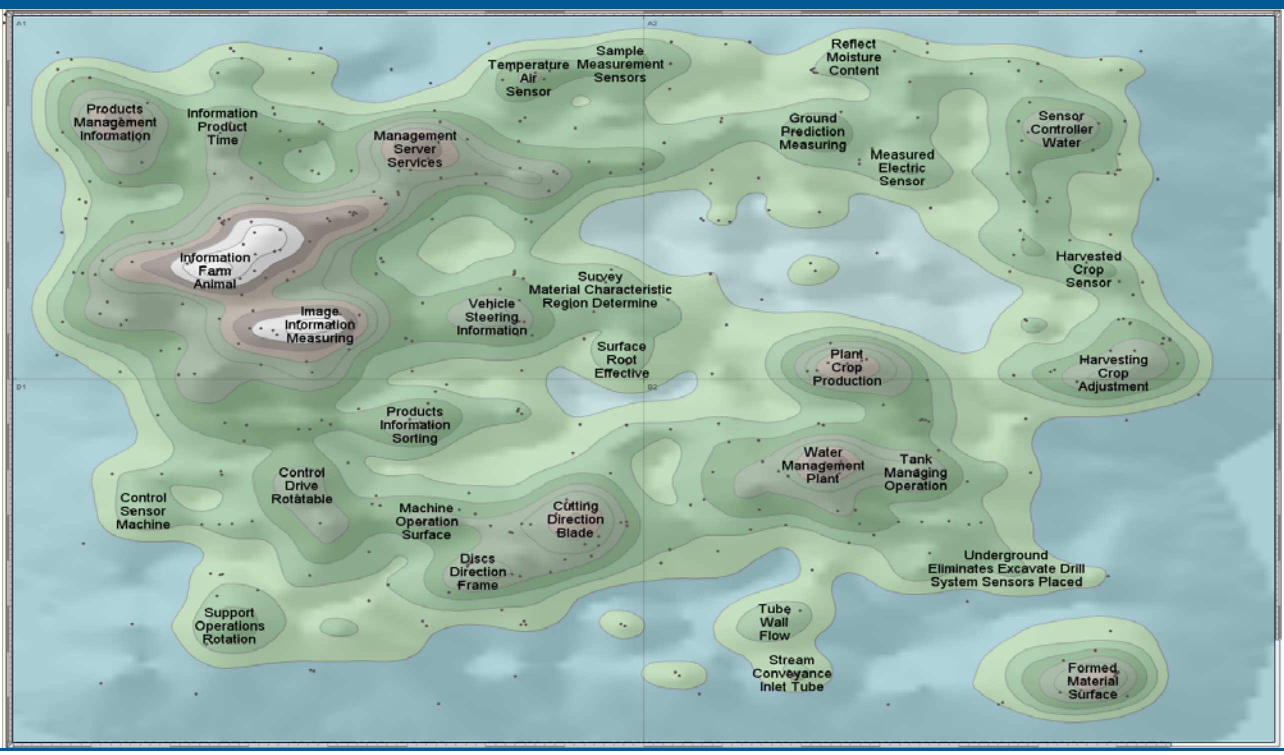
Source: Satellite Imaging Corporation, 2008.

everything from water and air quality to carbon stocks and nutrient deficiencies is the trajectory that monitoring activities are taking. Examples of this type of wireless sensor network have been used in a few scientific studies, but further development and assimilation could give us a picture of the ebbs and flows of the agricultural system. Precision agriculture technologies require a faster up-take rate by producers to utilize advanced information technology. Dependence on weather conditions, the risk of patent infringement and product liability issues, adverse foreign currency exchange rate fluctuations and uncertainty coupled with macro issues such as lower commodity prices and tightening credit are contributing to the industry's weakness.

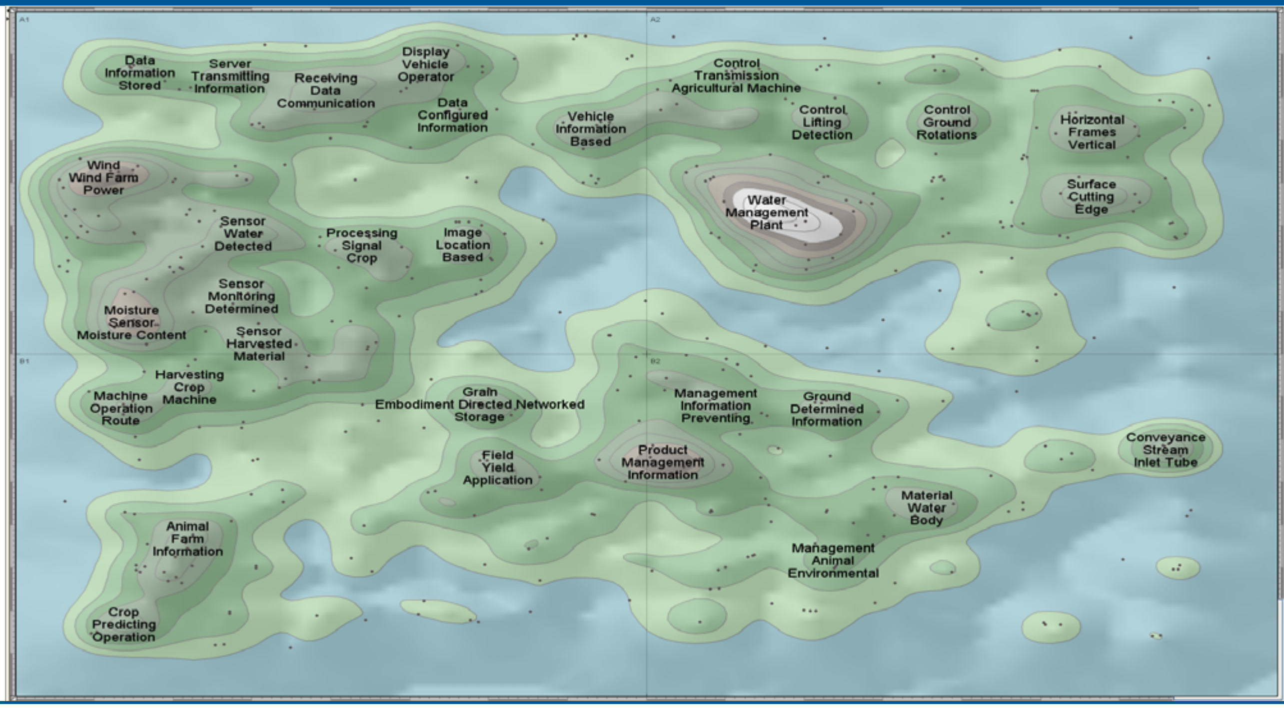
Technology Information – Patent Landscapes Using IP CHECKUPS

Patent landscapes highlight investment themes in a given sector. Technologies are grouped based on thematic, conceptual and contextual content enabling one to visualize how similar and competing technologies relate within a user defined landscape. We use these maps developed by IP Checkups to determine in which areas there are developments for our particular sub theme. Precision agriculture has seen significant investment activity as represented by the patent landscapes depicted below (See Exhibit 51). We also see how technologies have emerged over five and ten year periods. The map labels, situated on the "mountains", are the most prevalent concepts in a particular context. The highest "mountain" peaks show the largest number of patent documents in a technical area. The closer the documents are to each other, the greater the similarity is between them with respect to their contextual concept. We use these analytical visualizations in order to determine investment activity and opportunities in particular. In the Precision agriculture maps, we see a shift in the types of technology patents published from 1999 – 2004 versus 2004 – 2008. From 1999 – 2004, the primary concentration of patents was around information measuring and imaging technology. From 2004 – 2008, however, the concentration evolved around water management technologies on the part of plant uptake. Furthermore, information measurement technologies, such as sensors and data communication, became more sophisticated and therefore branched out to more precise technologies resulting in the clusters of sensor/signal and data retrieve patents as shown the second map below (Exhibit 52).

EX 51: Precision Agriculture 1999-2008: Competitive Patent Landscape Map (3134 Patent Documents)



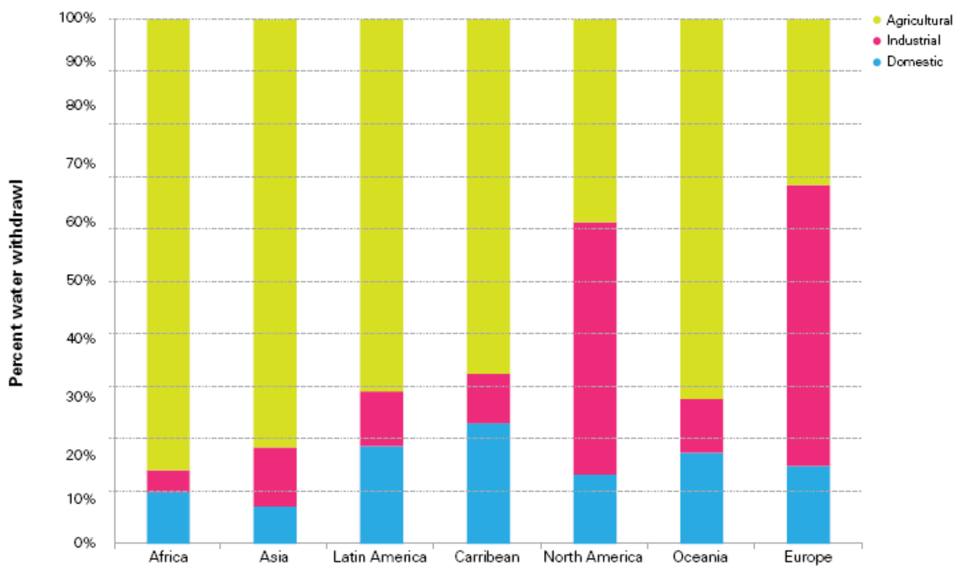
Ex 52: Precision Agriculture 2004 -2008. Competitive Patent Landscape Map (1278 Patent Documents)



Irrigation and Water-Use Efficiency

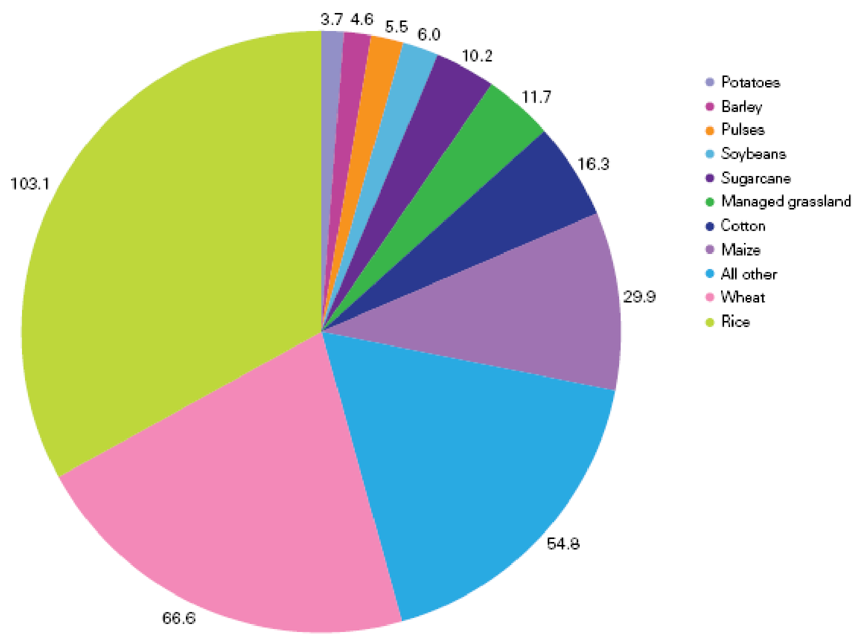
Irrigation is one way to ensure that crop water requirements are met. While only 18% of croplands are irrigated, 40% of crop production comes from those lands (Siebert et al. 2005) (Exhibit 53). The extent of irrigation has grown markedly, but it can cause problems such as water quantity depletion (aquifer or surface water), erosion and loss of nutrients from run-off, and soil salinization. In a hotter world, the ability to provide sufficient water for crop production will be a major challenge. Agriculture is already responsible for ~70% of freshwater withdrawals, and with limited exploitable water resources, the agricultural sector will need to use water more efficiently (Siebert et al. 2005) (Exhibit 54). Research and development are needed either to increase the production from the same amount of water or maintain the same production from less water. While it is clear that irrigation is essential to productive agriculture in areas without sufficient rainfall, there is significant room for improvement in this area.

EX 53: Freshwater withdrawal by sector (2001)



Source : Siebert et al. 2005

EX 54: Global sums of harvested areas of irrigated crop (Mha/year)

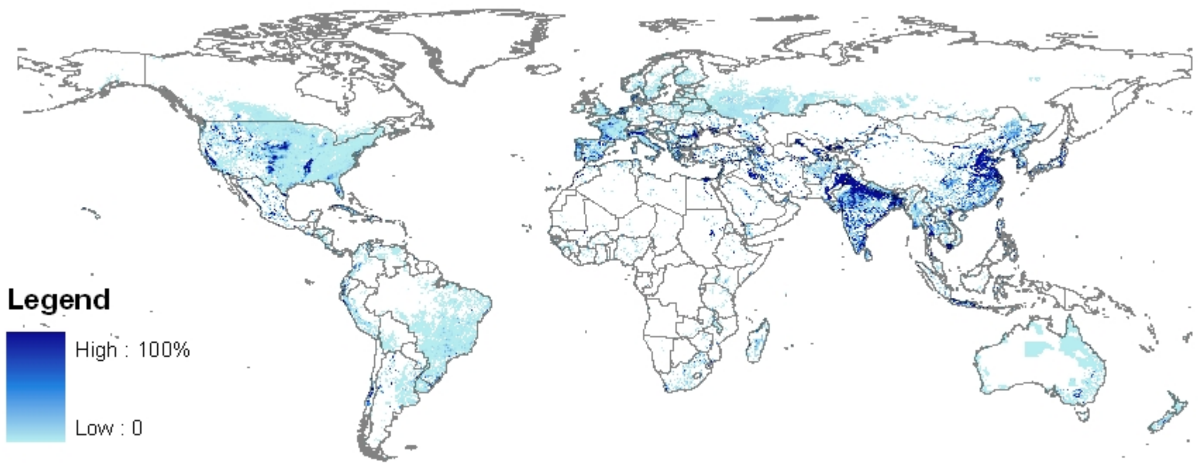


Source : Siebert et al. 2005

A collaboration between the Johann Wolfgang Goethe Universität, Frankfurt am Main and the Land and Water Development Division of the FAO produced a spatial data set of the global areas equipped for irrigation in the year 2000 (Siebert et al. 2005) (Exhibit 55). Combining this rich dataset with the SAGE crop maps, it is possible to create a global snapshot of the opportunities for increasing irrigation distribution and efficiency. In the exhibit below, the "Irrigated Area" panel shows the global extent of irrigation practices (Exhibit 56). The following chart compares irrigated maize yield versus rain-fed yield. This relationship holds true in most regions and for other crops as well.

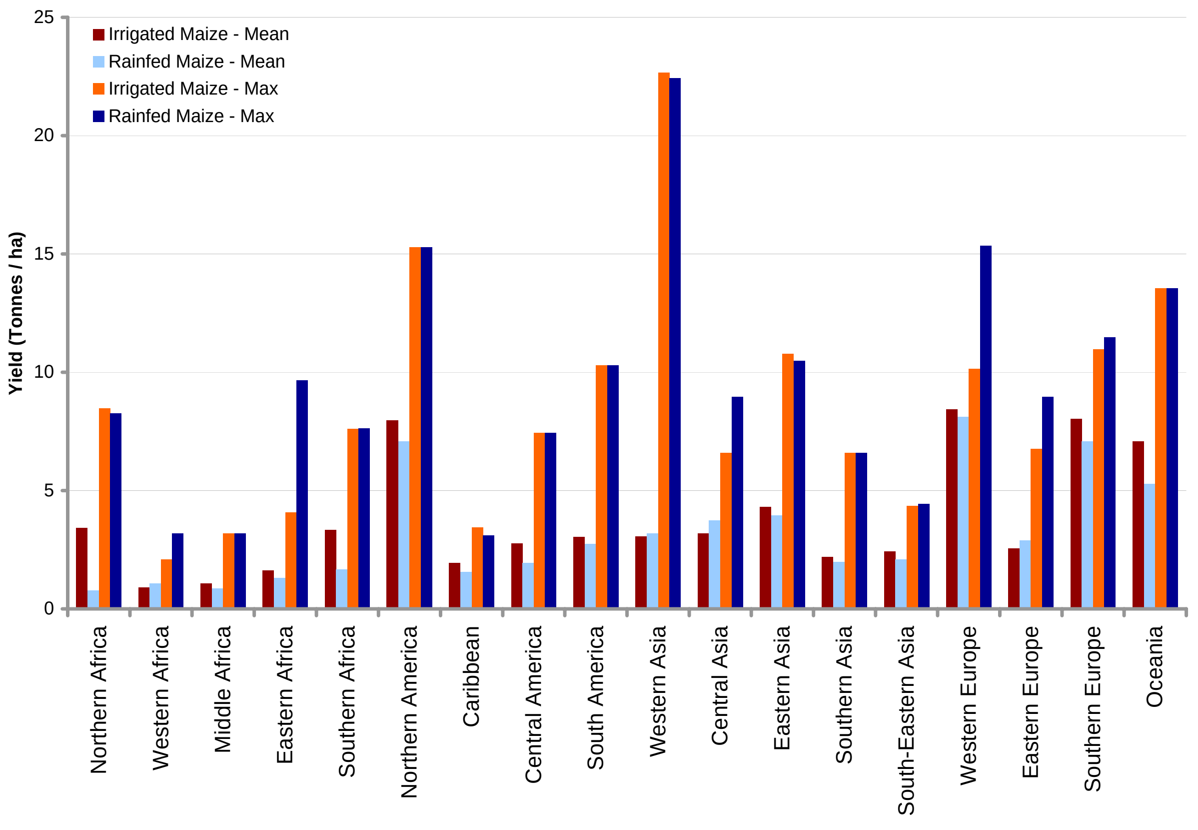
Closing the Production Gap

EX 55: Irrigated Area



Source : Siebert et al. 2005

EX 56: Yield differences between irrigated and rainfed maize

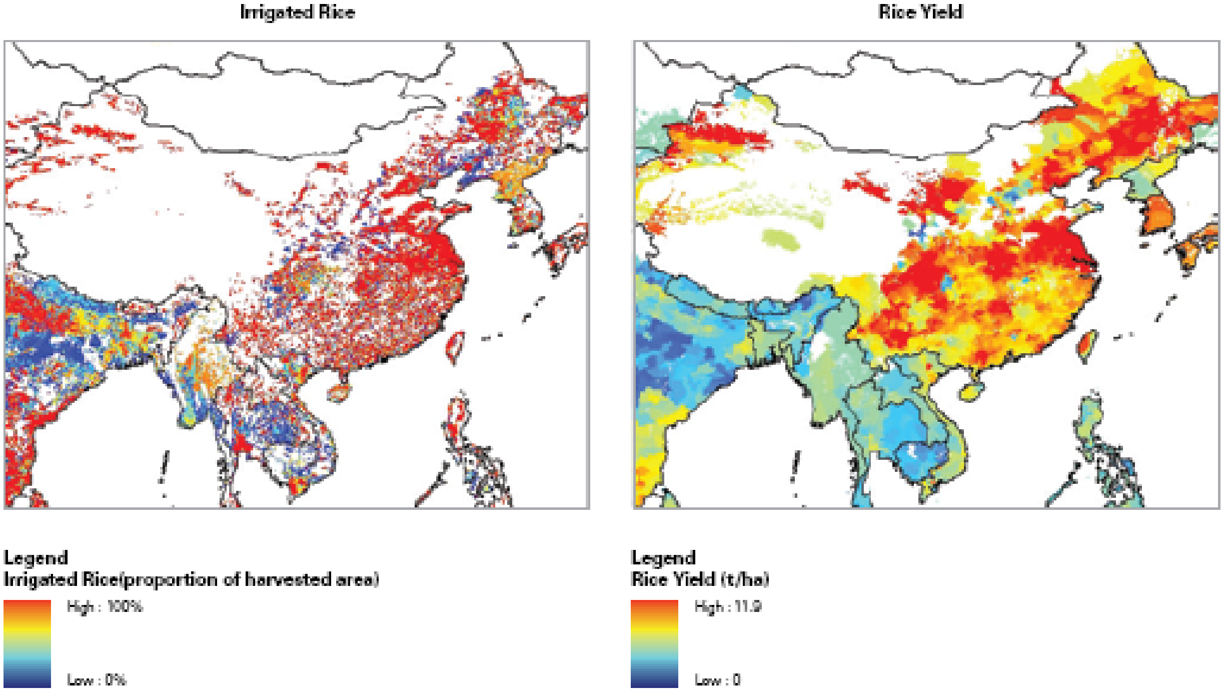


Source: Siebert et al. 2005, SAGE

Closing the Production Gap

While many factors control the overall yield of a crop, fulfilling the crop's water requirement is imperative. Rice in South-East Asia is one of the most heavily irrigated crops, and by comparing the irrigated area of rice with the yield of rice, it can be inferred that at least some portion of the yield gain is due to irrigation. This analysis is currently possible at a qualitative level only, and scientists are working to disaggregate the biophysical and management inputs that influence the yield of a given crop and in given regions. Here is an example of how GIS analyses help us discover areas where irrigation has improved rice yields and identify areas for improvement (e.g. deployment of irrigation systems). In Exhibit 57, there is a strong relationship between areas that are irrigated and areas that have higher yields. The irrigation practices may not be the most efficient, yet we are still able to see areas of under-utilization of water resources.

EX 57: Relationship of irrigation and yield

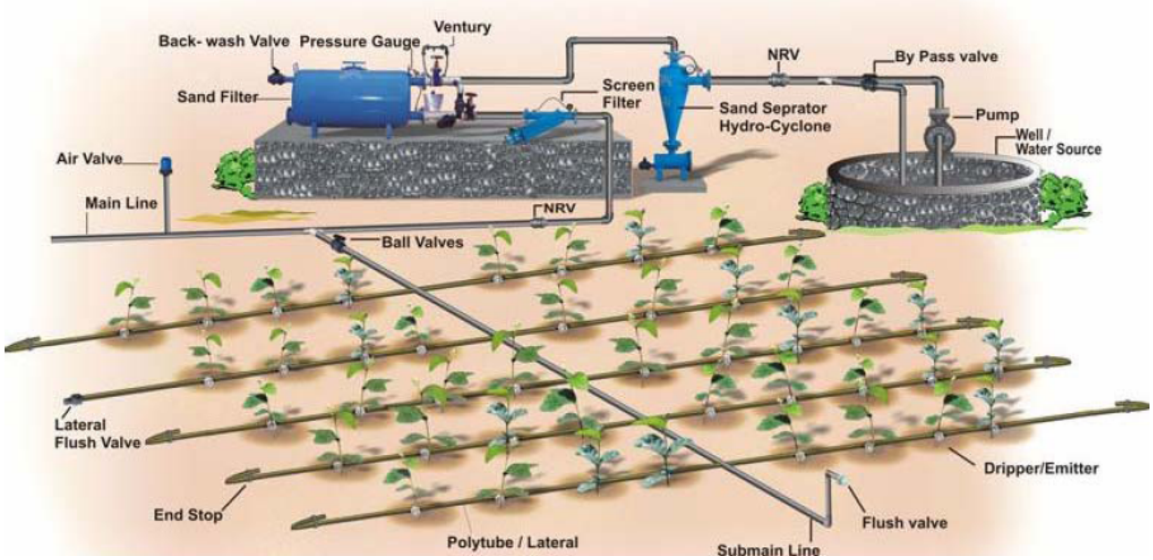


Source : Portmann et al. 2008, Monfreda et al. 2008.

However, we must realize that water stressed regions will provide limited irrigation water, therefore the rising demand for water conservation techniques on farms should constitute a clear opportunity. Innovative irrigation technologies must be developed in order to continue to raise productivity. Indeed, major investment in agricultural water use efficiency is needed before water scarcity goes from model projection to front-page headline.

Irrigation continues to be a major focus of the global agricultural value chain, as both established players and new entrants seek large growth in the sector. Recent growth has been seen through acquisitions, with both small and large companies acquiring irrigation technologies such as drip irrigation, which allows for low water-usage while still maintaining high yields (Exhibits 58 and 59). One such example is a major agricultural machinery firm that has declared a goal of significant growth in the irrigation sector. The firm has sought to enter the field in the drip irrigation sector by providing farmers with precision irrigation products. Firms in this area can gather data from planting, growth, and harvesting operations. This information can then be interpreted, distributed, and applied to crop production, providing better agronomic management, increased operations accuracy, and more efficient equipment use.

EX 58: Schematic Overview of Drip Irrigation System



Source: Jain Irrigation

EX 59: Comparison of Drip Versus Flood Irrigation

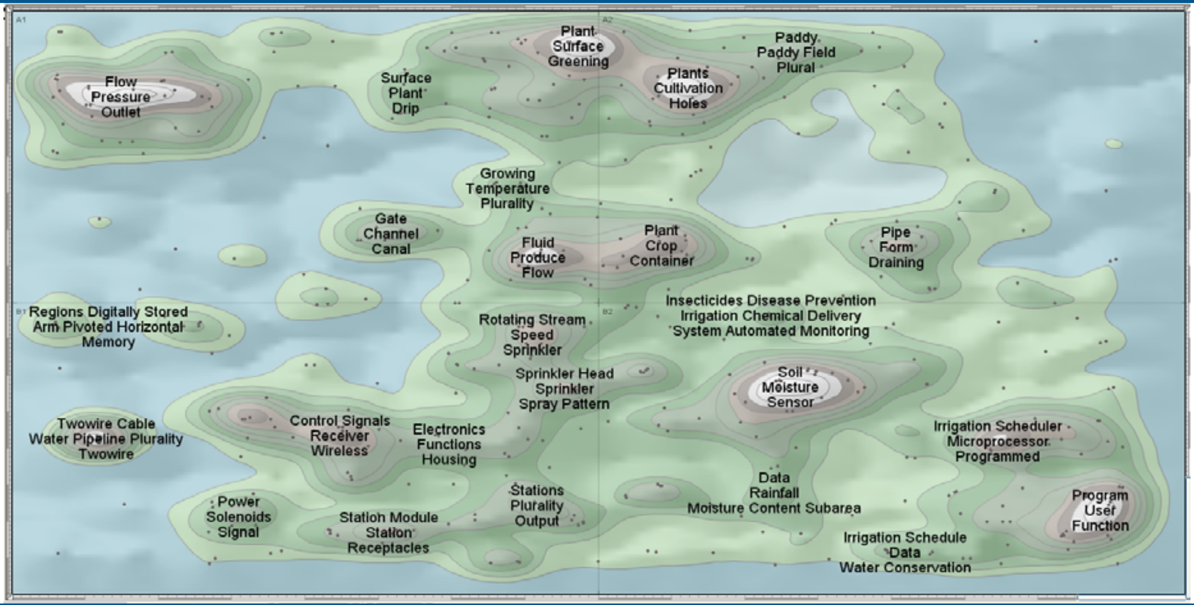
	Drip Method	Flood Irrigation
Water Saving	High 40-60% saving	Less High rates of evaporation, surface run off & percolation
Irrigation efficiency	80-90%	30-50%
Input Cost	Less spend on labour, fertilisers and pesticides	Higher
Efficiency of fertilizer use	Very high since supply is regulated	Heavy loss due to leaching
Water control	Can be regulated easily	Not much control
Yield increase	20-100% higher than flood method	
Capital cost/hectare	Rs 15,000-50,000 depending on crop spacing	

Source: Jain Irrigation

Closing the Production Gap

Our Smart Irrigation patent landscape illustrates where in the industry we are seeing development activity. Over ten years, patent velocity moved from water pressure and flow technologies to more activity in the area of data management. Furthermore, the maps below portray the consolidation of these irrigation technologies from 2004 – 2008, depicting greater synchronization among the technologies with one another over time. The consolidation has evolved to centralize around data management technologies, particularly with sensors and data retrieval, as well as structural and pipe technologies. This movement represents a clear growth prospect with close to half of the total patents published from 1999 – 2008 focused on this direction.

EX 60: Smart Irrigation 1999-2008: Competitive Patent Landscape Map (850 Patent Documents)

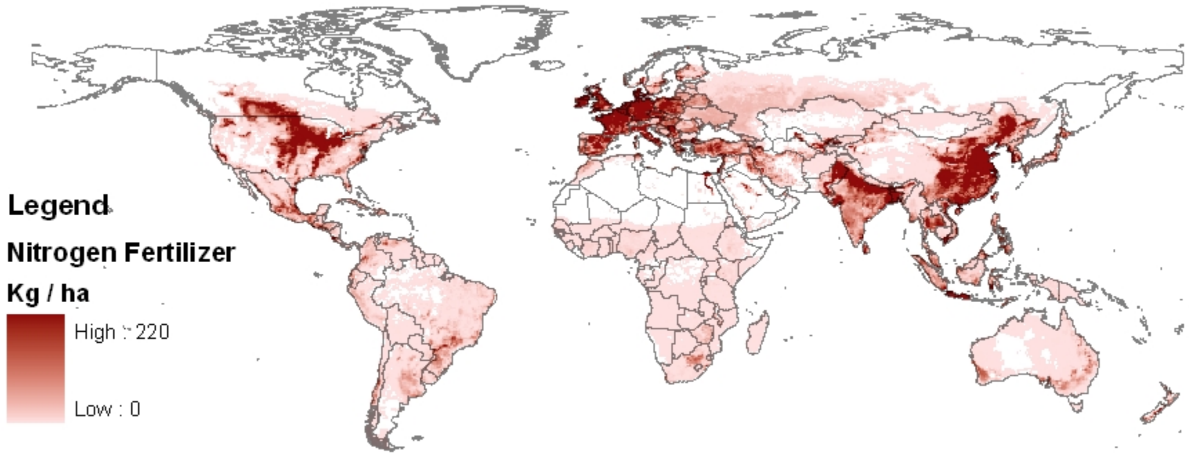


EX 61: Smart Irrigation 2004-2008 : Competitive Patent Landscape Map (396 Patent Documents)

Fertilizer

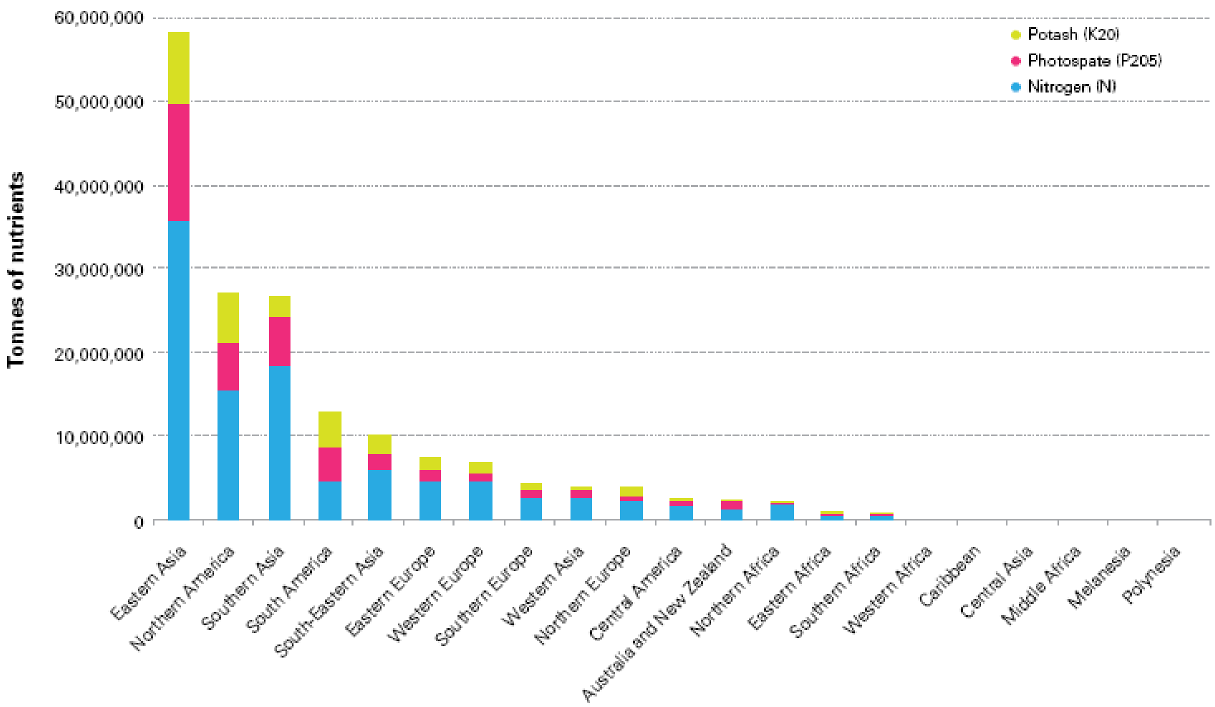
In areas of low soil fertility, fertilizers are used to supplement plant nutrition. In 2006, 170 million tonnes of the three major fertilizers (nitrogen, phosphorus and potassium) were placed on agricultural fields (Exhibit 62). Improper timing or over-fertilization can lead to serious problems that negatively affect air, water, land, and human health. Nitrogen fertilizer has the most wide-ranging potential consequences and solutions, hence our focus on it here (FAOSTAT, 2008, Exhibit 63). Nitrogen pollution from the United Kingdom and Germany is estimated to cost one third of the value of the crops and livestock produced there (Cassman et al. 2003).

EX 62: Nitrogen fertilizer application



Source: Ramankutty et al., unpublished.

EX 63: Fertilizer use

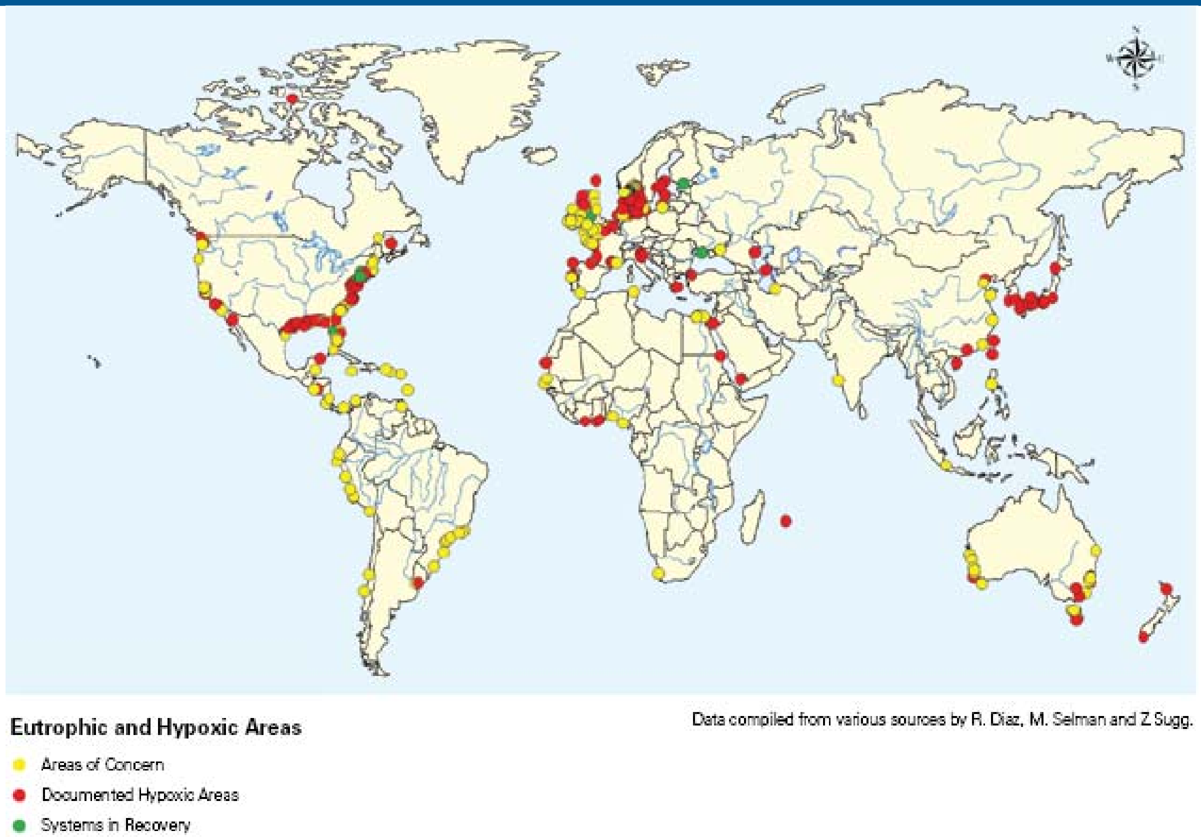


Source: FAOStat 2008

Closing the Production Gap

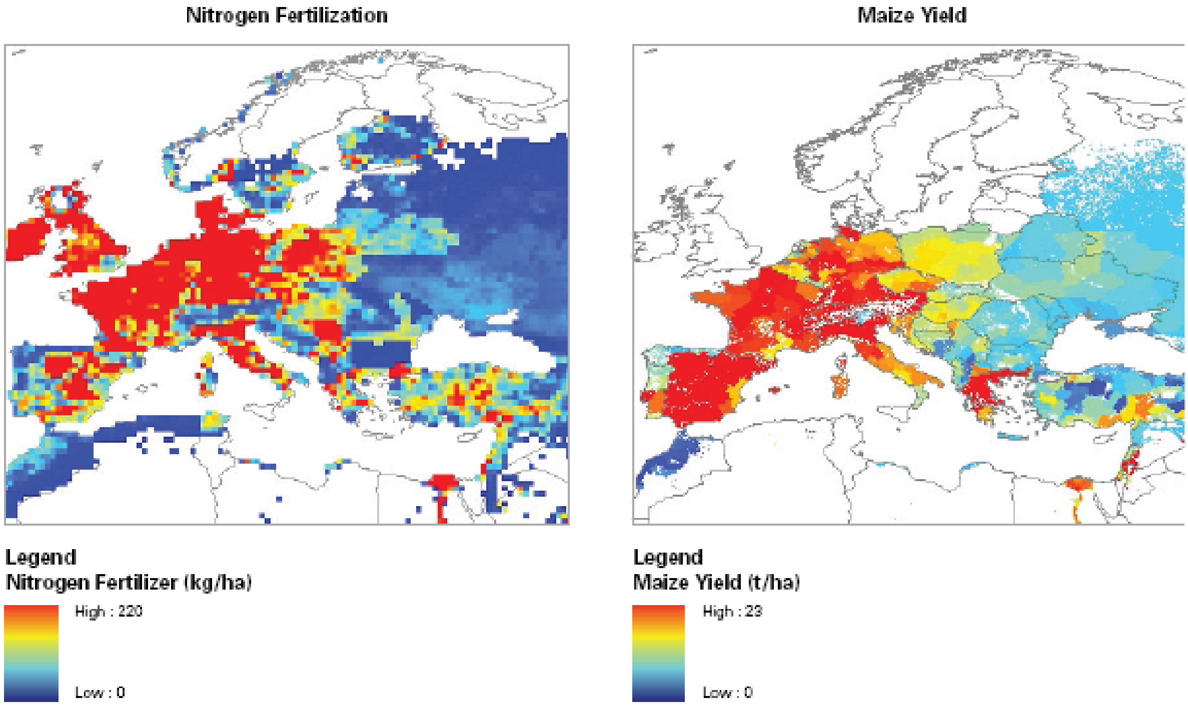
Today, about 40% of the world's population is dependent on nitrogen fertilizers produced by the Haber-Bosch process (Galloway et al. 2002). Nitrogen is essential to life and nitrogen fertilizers help feed us, but once it has left the farm field, nitrogen can cause problems. Wayward nitrogen from fertilizer is implicated in environmental problems from "blue-babies" syndrome due to nitrate in drinking water, to "dead zones" in the ocean, to global warming due to nitrogen-containing GHG's (Exhibit 64). The grand challenge presented here is to decrease the negative externalities of fertilizer use while increasing the availability of low-impact, highly efficient fertilizers in low-productivity areas. As farmers begin to adopt these fertilizers and practices, they can raise productivity while limiting the negative environmental impacts. This creates a win-win scenario for both the farmer and industries that are developing these products.

EX 64: World hypoxic and eutrophic coastal areas



Fertilizer is just one management technique used to raise yield, and the geographic patterns of fertilizer application can vary dramatically. For instance after the collapse of the former Soviet Union, application rates of fertilizer plummeted, and have only recently started to rebound. Western Europe, with higher rates of fertilization and other advanced management techniques, exhibits consistently higher yields. In the map (Exhibit 65) of fertilizer use in Europe, fertilization rates are also strongly positively related to yields of maize.

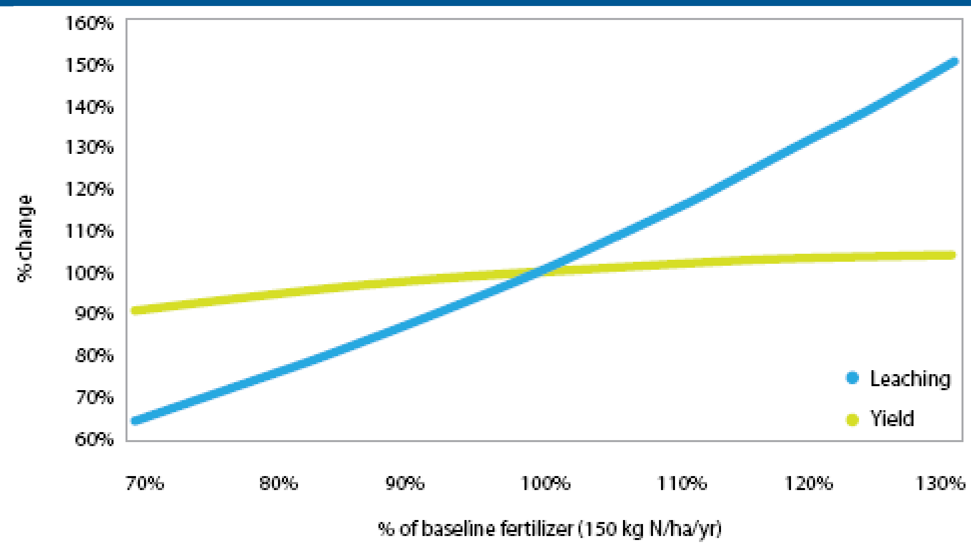
EX 65: Nitrogen fertilization and maize yield



Source: Ramankutty et al. Unpublished; Monfreda et al. 2008.

This analysis does not imply that we should indiscriminately apply nitrogen fertilizer on farm land. This is highly inefficient, since excess nitrogen use produces diminishing yield increases (Foley et al. 2005, Exhibit 66) and can cause dramatic fertilizer loss via nitrate leaching. Furthermore, such leaching has led to nitrogen pollution in many inland and marine ecosystems. We need to manage trade-offs between agricultural production on the land, drinking water safety, and the health and productivity of fisheries.

EX 66: Changes in corn yield and nitrate leading as functions of fertilizer application



Source: Foley et al. 2005

Closing the Production Gap

Yield of corn in the United States has risen from 1.6 T/ha to 8.6 T/ha between 1930 and 2001, largely due to increases in the use of nitrogen fertilizers. While the Corn Belt has enjoyed increases in yield, the rate at which this has been occurring has decreased from 3.4% / yr to 0.78%/yr, as the yield ceiling has been reached. Adding additional fertilizers is less likely to increase yields significantly as this ceiling is reached, but can result in more pollution-causing fertilizer run-off. In areas approaching their yield ceilings, the trade-offs between potential yield increases and environmental degradation from nutrient pollution must be weighed. (Foley et al. 2005)

When soils are water-logged for a period of time, nitrate from nitrogen fertilizer is converted to nitrous oxide by a process called denitrification. The Intergovernmental Panel on Climate Change has estimated nitrous oxide losses from fertilizer to be only about 1.25% of applied nitrogen fertilizer, but nitrous oxide has 310 times the global warming potential of CO_2 per molecule. In response to increasing concerns about the GHG emissions from the agricultural sector, academic and industry researchers are working to develop methods of decreasing emissions. While nitrous oxide emissions have already been reduced somewhat, scientists estimate that a further 30 Mega Tonnes (MT) per year of CO_2 can also be removed from the atmosphere by plants as a result of sound agricultural and forestry management practices.

Solutions to the fertilizer efficiency challenge include increasing the nitrogen use efficiency. This can be accomplished through changes in management (conservation tillage, timing of fertilizer application) and also through fertilizer technology and genetic improvements of crops. Fertilizer companies have conducted field trials showing increased nitrogen use efficiency in particular varieties of crops, including testing of genetically modified organism (GMO) crops. Some promising tests have shown that some crop varieties demonstrated high yields using significantly less nitrogen fertilizer than conventional varieties. Improvements were equivalent to using two-thirds less nitrogen fertilizer than conventional varieties to generate similar yields. This type of genetic improvement is an area of active investment today.

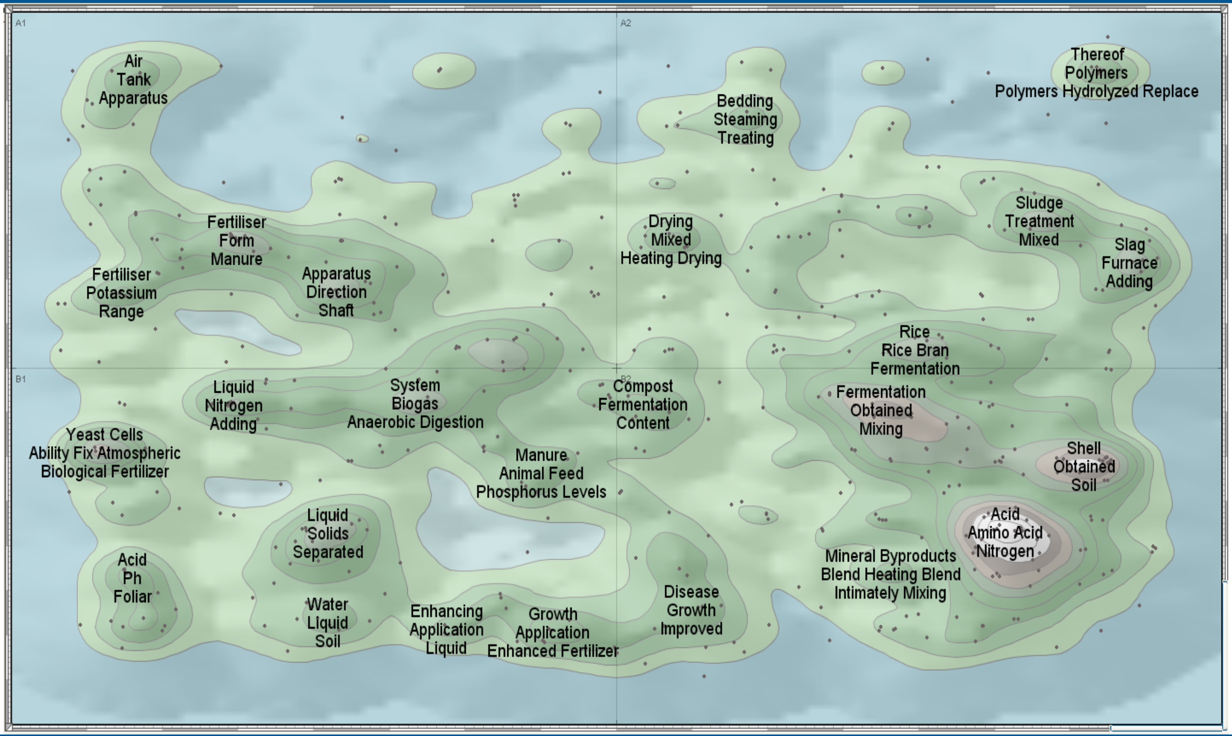
Advanced Fertilizers

The agricultural sector can decrease GHG emissions by adopting better management practices that minimize the amount of nitrogen in the form of nitrate present in soils during times when there is greater potential for denitrification. Potential mechanisms to achieve these goals include using split application, nitrification inhibitors, and controlled release fertilizers to match nutrient availability with crop needs over time. These tools prevent both greenhouse gas emissions and expensive losses of nutrients. Additionally, recent commercial research at over 42 sites in the US Midwest indicates that average corn yield response to polymer-coated urea fertilizer was 5 bu/acre higher compared to that of conventional urea, especially during years of normal or high rainfall.

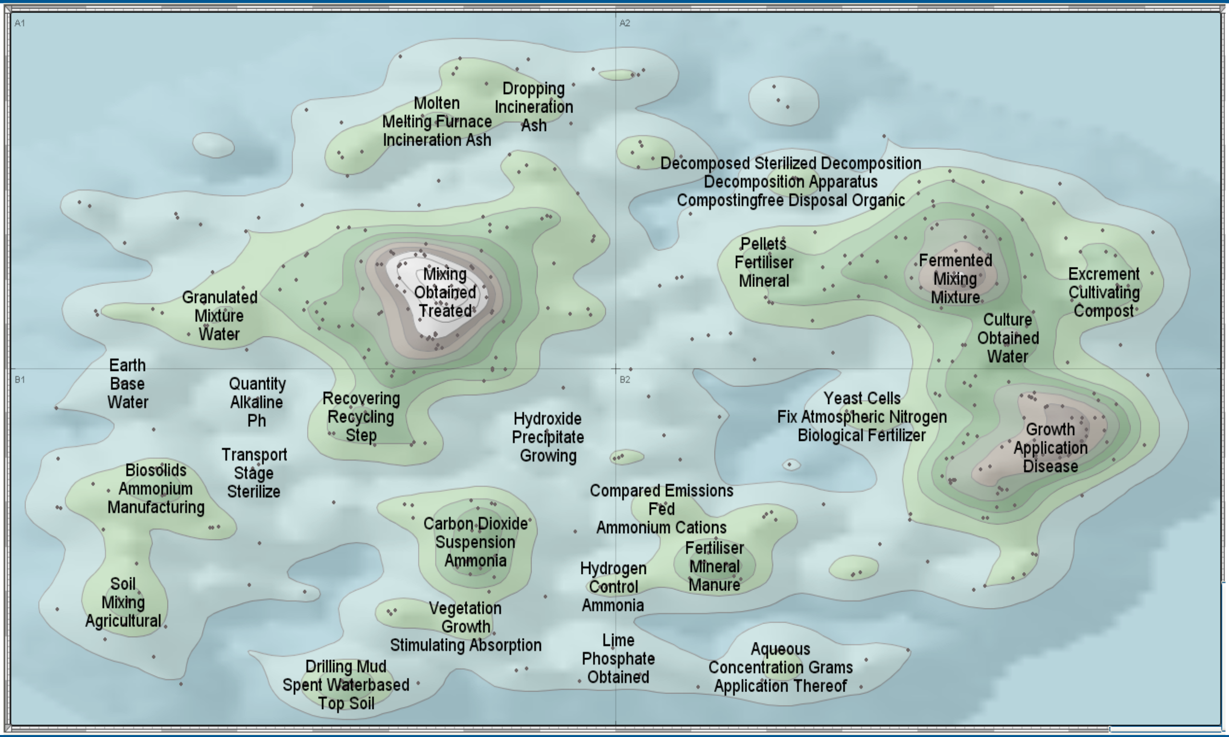
Management strategies to reduce soil nitrogen loss include improved timing of nitrogen fertilizer applications, better use of soil and plant testing procedures to determine nitrogen availability, switching to use of variable-rate nitrogen fertilizer applications and other more effective nitrogen fertilizer application methods, application of nitrification or urease inhibitors, and use of nitrogen fertilizer sources that are suitable for local environmental conditions. By improving the efficiency of fertilizer and water, emissions of nitrous oxide could be significantly reduced. Our fertilization patent landscapes illustrate more activity in the area of protein development to mining technologies that reduce pollution (Exhibits 67 and 68). Despite this shift, the majority of patents published over the past ten years still focused distinctly on protein development, such as acid, shell and fermentation technologies. In recent years, fertilizer development has diverged significantly, as depicted by the second map below; however, these patents compose only a minority of the total patents published over the past ten years, showing a growing but still early trend.

Closing the Production Gap

EX 67: Sustainable Fertilizer 1999-2008: Competitive Patent Landscape Map (1647 Patent Documents)



EX 68: Sustainable Fertilizer 2004-2008: Competitive Patent Landscape Map (582 Patent Documents)



Closing the Production Gap

Agricultural Machinery

Agricultural machinery companies are planning to meet the challenges created by global trends. These include the significant emerging demand from developing markets such as the BRIC countries, increased bio-fuel production, and the rise of mega-farming operations. Agricultural equipment is becoming more advanced, with improvements in high-performance spraying, harvesting and construction equipment, as well as smaller tractors and upgraded utility vehicles. The trend has been growth in the sales of agricultural tractors in Asia, yet more recently, however, Russia has begun to see more investment in the agricultural sector, including more investment in tractors.

Precision farming products that optimize efficiency in farming operations are becoming more prevalent in developed agricultural economies. They include an integrated machine with components for increased accuracy, advanced guidance systems and display options, as well as comprehensive information management. Some advanced machines now allow low-soil-disturbance. Machines that are able both to plant seed and apply fertilizer can fertilize more accurately and reduce input costs and reduce environmental impact. Other innovations include reduced engine emissions, improved fuel efficiency, controls over nitrogen oxide emissions, and the ability to work around the retained crop residues in reduced tillage systems. Agricultural machinery that can increase output, use less fuel and cause less soil compaction is highly desirable.

We know, however, that the growing demand for agricultural equipment will come from the lower end of the agricultural market, for instance from developing countries like India. Therefore it is imperative that investments drive the costs of these technologies down in order to reach the developing economies' agricultural sectors.

Infrastructure

In order to raise productivity across agricultural regions, significant investment must be made into the infrastructure of agriculturally productive regions. GIS systems can help policy makers identify where infrastructure investments should be placed in order to connect farms at all production levels. In some cases agricultural productivity is high and it is only a matter of logistics to store and transport the produce from one region to another. While infrastructure development takes time, leading companies in supply chain management in developing countries and emerging economies have capitalized on the dismantling of inefficient and bureaucratic agricultural systems. These companies are involved in establishing transparent financial and efficient logistics networks, including prepayments for farmers, guaranteed off-take at market prices before the planting season, and re-deployment of underutilized legacy processing assets. The first-mover advantage in origin markets and the strong relationships in end markets create high barriers to entry. Some agri-giants would regard investing in infrastructure for origin markets of developing countries as too small or too risky.

Farm Commercialization

Farm commercialization, the shift toward use of sophisticated farming methods and inputs that results in greater and more consistent output, has the potential to raise agricultural productivity across the globe. The relationship between fertilizer application, irrigation and crop output is closely linked and the rate of commercialization will drive other input growth rates (Exhibit 69). In developed economies, farmers have already commercialized their operations and have optimized their practices to maximize output, whereas in emerging economies it is less so. Clearly, maximizing output needs to be moderated by the need to protect environmental resources. However, many developing economies are seeking agricultural policies that favor food self-sufficiency, including China, Russia and other nations (Exhibit 70). It is the commercialization of the factors of production that will raise productivity. Since the commercial farm is typically much larger, it often integrates food/fuel/waste elements, and enjoys significant yield and cost advantages. The result of such commercialization is a global increase in current and expected farm income levels. That in turn may drive higher rates of private investment in farming, and foster critical changes in agricultural policies across most of the world's largest agricultural economies. This is an active area for policy makers and therefore investors must pay close attention to these trends.

Closing the Production Gap

Education, tools and investment capital are needed to increase production and to incorporate new management techniques into local, regional and global markets. There are limits to commercialization however. For example, the increase of the meat and soybean export market from Brazil to other countries since 2000 is correlated to deforestation (Zaks et al. submitted). Additionally, commercialization does not necessarily mean exponential growth in size of operation. We simply mean that farmers, regardless of scale, must professionalize their management, both in terms of raising productivity, protecting vital environmental resources and capturing the opportunity of the emerging offset markets. We must also provide policies that protect forests and other high value ecosystems from detrimental shifts in land use.

EX 69: Farm Commercialization drives agricultural input growth rates

	1-5 years	5-10 years	10-20 years	20+ years
Farm Commercialization Pace	Slow	Rapid	Mixed	Declining
Fertiilzer Demand Growth	Moderate	High	Moderate	Slow
Ag Chemical Growth	Moderate	High	Moderate	Declining

Source: Credit Suisse, 2008

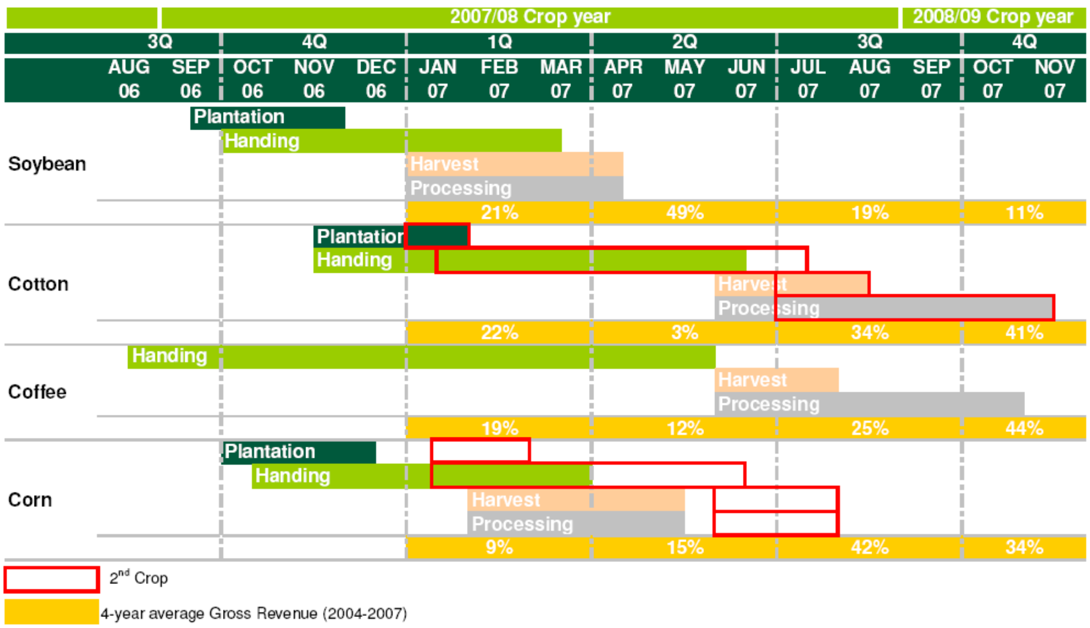
EX 70: Farm Commercialization drives agricultural input growth rates

Region	Extent of Commercialization	Time to Commercialization	Key Impediments
Brazil & Argentina	Advanced	-	Financing, lagging infrastructure development
Russia	Moderate	7+ years	Land ownership, de-centralized Ag policy, infrastructure
Eastern Europe	Moderate	5+ years	Land ownership, land/water quality
China & Suotheast Asia	Limited	10+ years	Land/labor issues, poor water quality
Mexico & Central America	Limited	10+ years	Limited infrastructure development, limited access to capital, land transfer issues
Middle East & Nortern Africa	Limited	10+ years	Limited water supply, under utilized fertile land
Africa	Very Limited	20+ years	Labor issues, limited infrastructure, potential instability
Pakistan & India	Very Limited	20+ years	Labor issues, limited infrastructure, government involvement limits farming profitability
USA	Developed	-	Already at high levels
Europe	Developed	-	EU Ag policy toward GM seed

Source: Credit Suisse, 2008

We would like to highlight an example of how farm commercialization is working. We will use SLC Agricola, the largest listed Brazilian farm-operator, with over 30 years of experience in the Agribusiness sector, which is one of the largest Brazilian producers of soybean, cotton and corn and has one of the highest yields among producers in Brazil and Latin America. Their 10 farms are strategically located in the Savannah Region of Brazil. They are highly experienced in the acquisition of undeveloped farmland with significant appreciation potential and have a professional management team with proven execution capacity. Their ability to acquire and develop large areas of farmland in non-obvious regions has resulted in a diversified portfolio of production systems. In addition, their strategic and diversified location of properties, and a mix of owned land and leased land, has reduced potential productivity risks such as regional climatic risks, losses from pests and diseases, etc. Also a flexible crop portfolio, including double cropping, maximizes their land utilization. They practice state-of-the-art production and maintain continuous investments in research and development, resulting in higher yields. They use automated heavy equipment with GPS technology, a crop rotation system (cotton, soybean and corn), soil correction methods, highly selective seed pool and a no-till technique. Their production cycle is highlighted below (Exhibit 71).

EX 71: Production Cycle



Source: SLC Agricola

We feature this system because to us it exemplifies how land selection, adoption of technology, and expert/professional farming practices leads to higher agricultural efficiency and productivity.

Agricultural Risk Management and Insurance

A number of risk management tools such as crop and yield insurance can help farmers manage the volatility of prices, yields, government policies, and foreign markets. This area of agricultural risk management and insurance is ripe for investment and development, especially in areas with harsh climates. State-sponsored agricultural insurance has been in place for many years in the US and is currently being greatly expanded domestically and abroad. A risk partnership between agriculture, the state and the insurance industry would have great advantages in protecting farmers and allowing them the opportunity to commercialize.

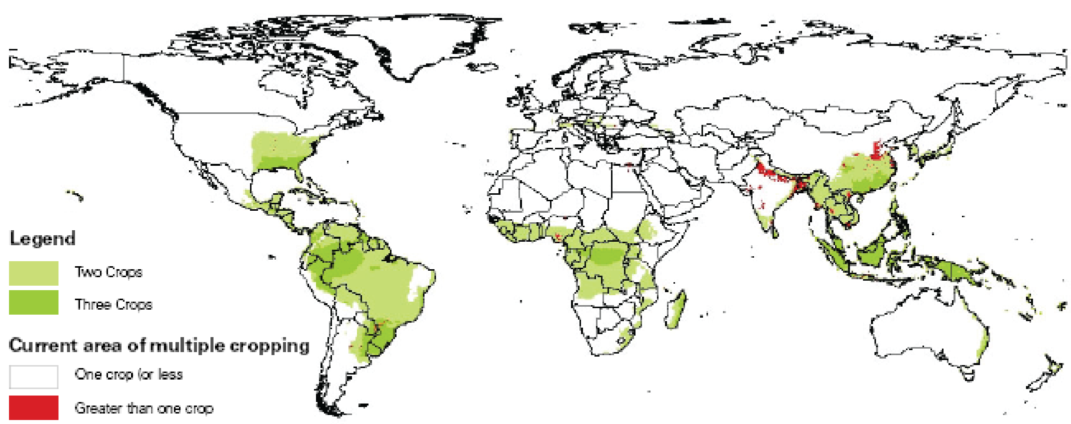
Insurance pays for losses based on an independent and objective measure that is highly correlated with the losses. For example, suitable triggers in agricultural insurance can be lack of rainfall, extreme rainfall, freeze, average yields per region or municipality. With the exception of hail insurance, most crop insurance has involved heavy subsidies to mitigate the expense of the premiums. For example, both the United States and Canada have three forms of subsidy: 1) a direct premium subsidy, 2) subsidy in the delivery costs, and 3) some form of government sharing for the most catastrophic risk.
The world experience with multiple peril crop insurance has been particularly troublesome because the amount paid by the farmer is typically a fraction of the total cost of delivery and underwriting of this form of insurance. For example, in the United States, the farmer pays only about 30 percent of the total cost. In middle-income countries that have tried multiple peril crop insurance, direct subsidies have typically been lower. Farm households make up a small fraction of the population in most of the countries that provide subsidized crop insurance. The same is not true in many lower-income countries, which makes it even more unlikely that lower-income countries can afford to adopt the practice of subsidized crop insurance. Of course, no country can afford to implement a crop insurance program fraught with problems that result in extremely poor actuarial performance. Furthermore, when there are large numbers of households that operate small units, it is increasingly expensive to control the adverse selection and moral hazard that lead to poor actuarial performance. Clearly, the focus must be on how to make insurance more affordable for lower-income countries and still give private interests incentives to cooperate, get larger and commercialize.

Land Supply / Land Use Response

Feedstock production for biofuels competes for land needed for present and future food production. If we are both to feed a growing, more affluent population and to use alternatives to fossil fuels, innovation and collaboration is need across many industry sectors to rise to the challenge of sustainably producing biofuels. Quantifying the land-use and energy implications of the next generation of biofuels is going to be key in ensuring their sustainability. Khosla (2008) presents an example rubric named CLAW, in which future biofuels must (C)ost less than gasoline, have low to no additional (L)and use, have limited impacts on (A)ir quality (i.e. carbon emissions) and limited (W)ater use. Similar to increasing agricultural productivity, there is no "silver bullet," but a diverse mix of technologies and feedstocks that can help to power the future.

Leveraging several studies, we aim to show the location of lands that could be used to provide feedstocks for second-generation biofuels, and do not compete for land required for current or future food production. The MIT analysis outlined in Box 1 pointed to the importance of land use switching for biofuels development. Cropping intensification is always favored over extensification, and there are many areas around the world that can support more than a single crop harvest. The Global Agro-ecological Zones project led by the International Institute for Applied Systems Analysis (IIASA) mapped the multiple cropping potential of rain-fed production by computing the length of the growing season as defined by the seasonal patterns of temperature and precipitation. In parts of the humid tropics it is possible to have three continuous crops of rice; in temperate regions it is possible to grow winter wheat or other cover crops during the fallow cycle of summer crops. It is always preferable to plant a low to no-input crop that also helps to rebuild soil carbon and structure, instead of leaving bare soil that is prone to erosion. Using the SAGE cropland data, multiple cropping can be identified as any place in which the harvested area exceeds the cropland area. The majority of these places are in northern India and China, which leaves many other agricultural lands available for low-input cover crops that can be used as biofuel feedstocks (Exhibit 72).

EX 72: Multiple cropping potential

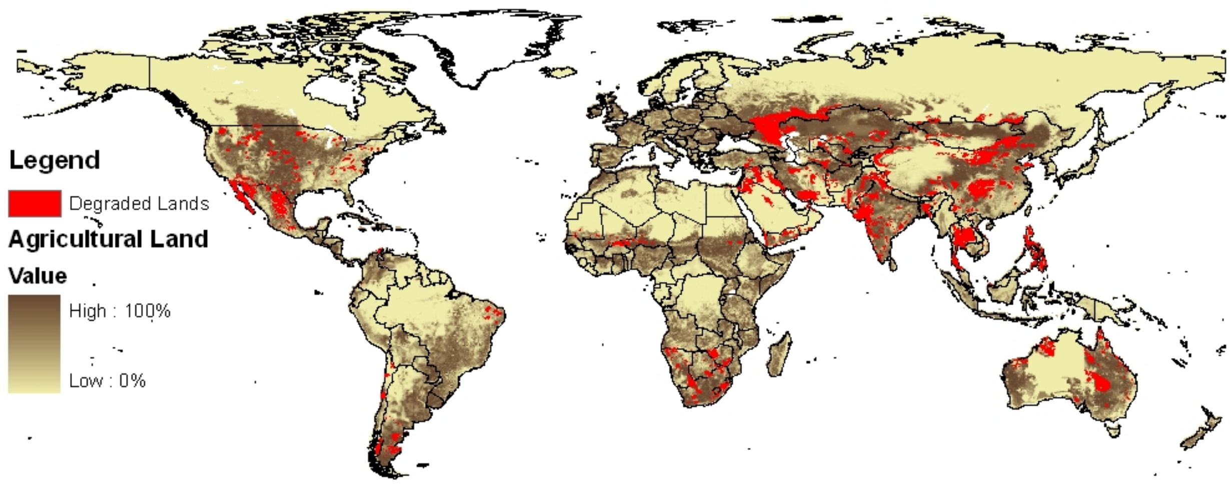


Region	Total suitable (million ha)	Single cropping (%)	Double cropping (%)	Triple cropping (%)
Oceania	87	83	13	4
Asia	366	63	32	5
Africa	678	59	39	2
Europe and Russia	422	100	<1	0
South and Central America	606	19	65	17
North America	297	57	30	13

Source: IIASA GAEZ, Monfreda et al. 2008

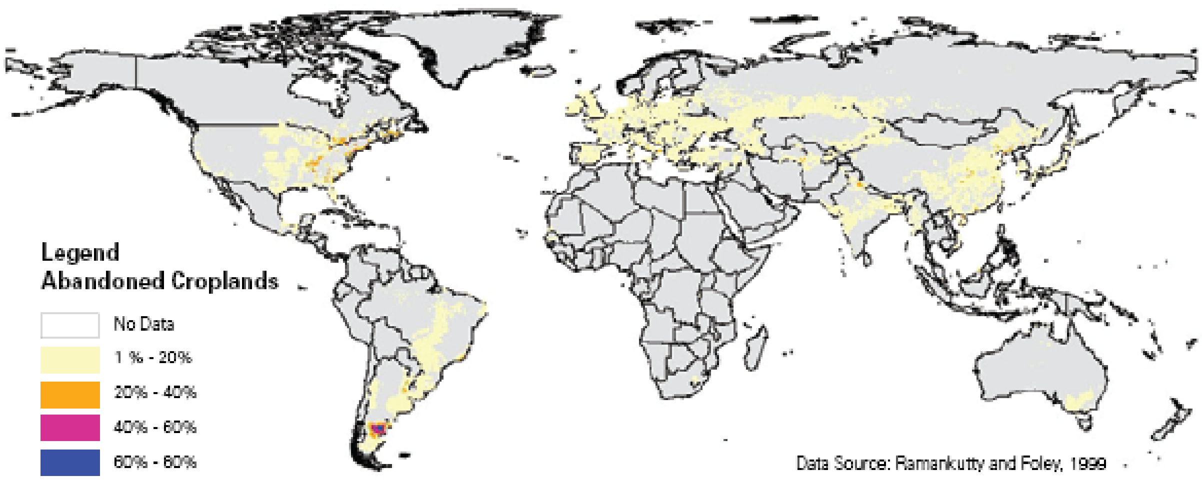
Where intensification is not an option, lands not currently in production or not suitable for food production can be used to grow second generation biofuel feedstocks. One category of land that can be used is degraded lands (Exhibit 73). This is possible largely because the perennial plants that produce second-generation biofuels generally do not require tillage, and can be sustained on otherwise erodible land. The last comprehensive estimate of degraded lands was the Global Assessment of Land Degradation (GLASOD), conducted in 1990, that found over 1900 million hectares of degraded land globally, almost half of it moderately degraded (Oldeman, L. R. et al. 1990)). A more modest estimate reported by Hoogwijk et al. (2002) is 430-580 million hectares of degraded land. Most of this degradation occurred because of poor agricultural practices (Cassman et al. 2002). The Millennium Ecosystem Assessment (MA, 2005) adapted the GLASOD data for its analysis, and it is displayed here with agricultural land (both pasture and cropland). While degraded lands might not be suitable for food production, there are opportunities to rehabilitate the land and bring it back into production or to plant crops that can tolerate sub- prime growing conditions, such as jatropha. A co-benefit of rehabilitating degraded lands is the resultant belowground carbon sequestration.

EX 73: Degraded crop and pasture lands



Source: SAGE, 2009.

EX 74: Non-forested abandoned croplands

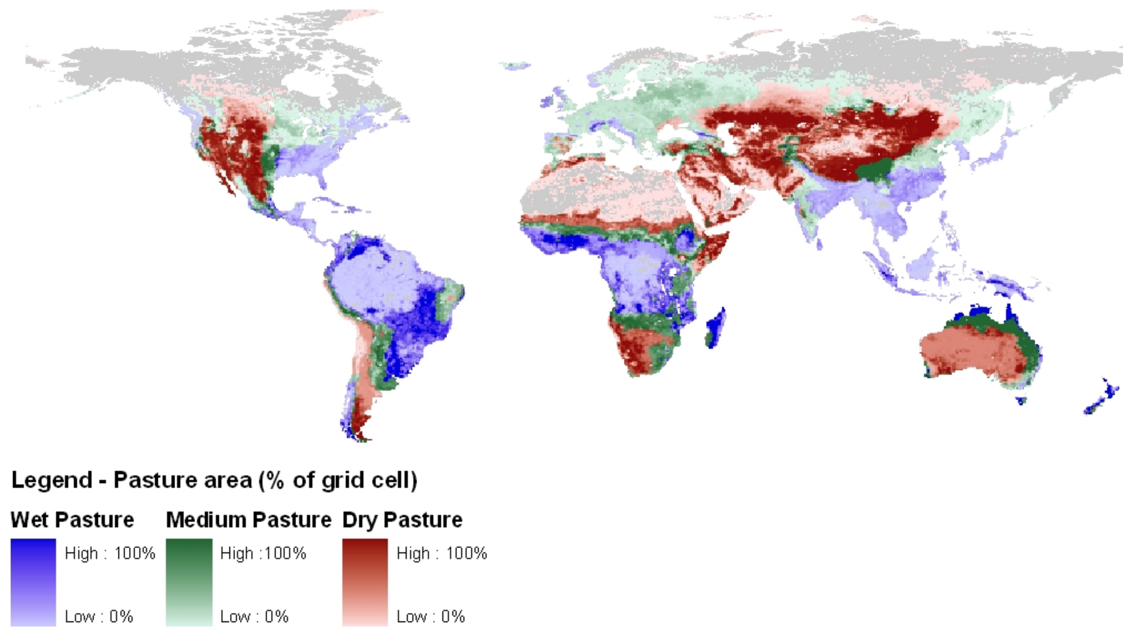


Source: SAGE, 2009.

Studies of the historical distribution of agricultural lands help locate land that was previously cropped, but has since been abandoned (Campbell et al. 2008, Ramankutty and Foley, 1999). It is traditionally held that previously cropped land has limited ecological value with less biodiversity, soil carbon and other indicators of ecosystem health than undisturbed lands (unless it reverts into previous land cover). For this analysis, the SAGE historical croplands database was used to identify the maximum extent of agriculture for every location on earth and compare it to its current day extent (Ramankutty and Foley, 1999). If the historical maximum of cropland area is greater than the current extent, one can assume that there exists abandoned cropland. A similar study conducted by Campbell et al. (2008) estimated that there exists 385-472 million hectares of abandoned agricultural land. Some of these abandoned agricultural lands could have been degraded, therefore the figures of degraded land and abandoned agricultural land are conflated (Exhibit 74).

Another potential land resource for second-generation biofuels production is highly productive tropical pastures. While pastures currently support livestock populations, the potential energy that is captured by tropical grass is transferred very inefficiently to livestock, and it may be in the societal best interest to harness the production of these lands for second-generation biofuel feedstocks. If biofuel feedstock production were to displace livestock in tropical areas, it would be crucial to prevent forest clearing in other areas, as that would negate any carbon benefit of the biofuels. The map highlights pastures and the rainfall that they receive. The intensity of the color refers to proportion of pasture in that area (Exhibit 75).

EX 75: Productive pastures for potential biofuel production



Source: SAGE, 2009

Thus far, we have described the land that could be available for second generation biofuels production, which includes feedstocks such as switchgrass, jatropha, miscanthus and fast-growing trees like poplar. First generation biofuels are high-input and low-diversity systems (i.e. maize, sugarcane, soybeans), but a team from the University of Minnesota led by David Tilman suggests using low-input, high diversity (LIHD) native perennial grasses (i.e. second generation) as a feedstock (Tilman et al. 2006). As opposed to annual crops, perennial crops build up below-ground carbon in roots and the soil, which gives them the potential to store carbon. Their calculations show that LIHD biomass yield "51% more usable energy per hectare from degraded infertile land than does corn grain ethanol from fertile soils" if converted using integrated gasification and combined cycle technology with Fischer-Tropsch hydrocarbon synthesis (IGCC-FT) (Tilman et al. 2006). Globally, if LIHDs were planted on 500 million hectares of abandoned or degraded land, it could displace approximately 13% of liquid fuels for transportation and 19% of global electricity consumption (Tilman et al. 2006). If this approach is used, enormous investments in infrastructure, conversion and delivery of these fuels will be necessary.

Land Supply / Land Use Response

EX 76: Opportunities for Biomass Production for second generation biofuels

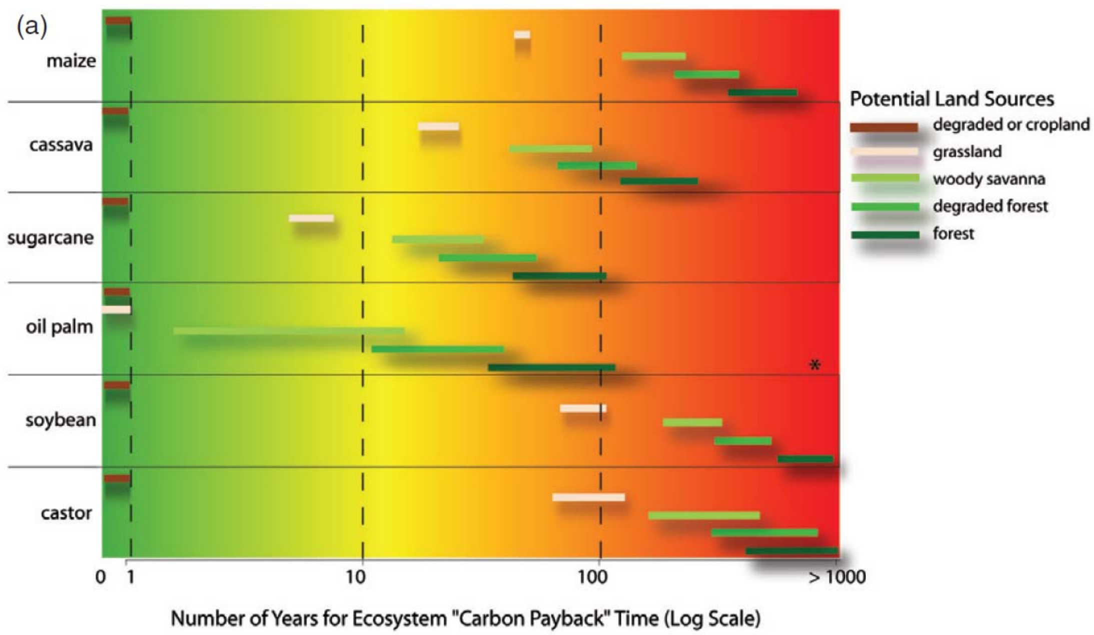
Biomas Source	Potential Energy Supply in EJy-1
Biomass production on surplus agricultural land	0-988
Biomass production on degraded land	9-110
Agricultural residues	10-32
Forest residues	42-48
Animal manure	9-25
Organic wastes	1-3
Bio-materials	83-116

Adapted from Hoojwick et al. 2002

Land supply converted for use in biofuel production can help close the widening yield gap. If we move from first generation to second generation feedstocks for biofuels, then we can limit the land competition with food production (Exhibit 76). Also on the horizon is the use of algae to produce biodiesel, or to produce hydrogen directly. The land footprint of algae operations is expected to be significantly smaller than that of second generation biofuels. Again, comprehensive governmental policy would need to monitor and manage the conversion of food producing lands to fuel-producing lands.

Box 4: Carbon payback

Recent studies by Searchinger et al. (2008), Fargione et al. (2008) and Gibbs et al. (2008) have shown the importance of applying life-cycle analyses to the production of biofuels. Biofuels were once thought to be a climate-friendly energy source, but these recent analyses have accounted for the CO2 emissions from land conversions to grow biofuel crops, including the expansion and shifting of agriculture needed to fulfill biofuel mandates. The ecosystem 'carbon payback' time (ECPT) is an index that gauges the length of time it would take for agricultural biofuels to offset the CO2 emissions from clearing carbon-rich ecosystems. For instance, peat forests in South-East Asia that store large amounts of carbon have a very long "payback time" if cleared, while biofuel crops planted on degraded land, abandoned land or previously cleared land have a much quicker "payback time." We need to prevent putting in new biofuel crops into areas of forestland that store large amounts of carbon.
The exhibit below illustrates the ECPT for several biofuel feedstocks in tropical areas (where most first-generation expansion in expected to occur) and how that payback time varies between previously cleared lands and natural ecosystems.



Data source, Gibbs et al. 2008

Biotech Crop Options

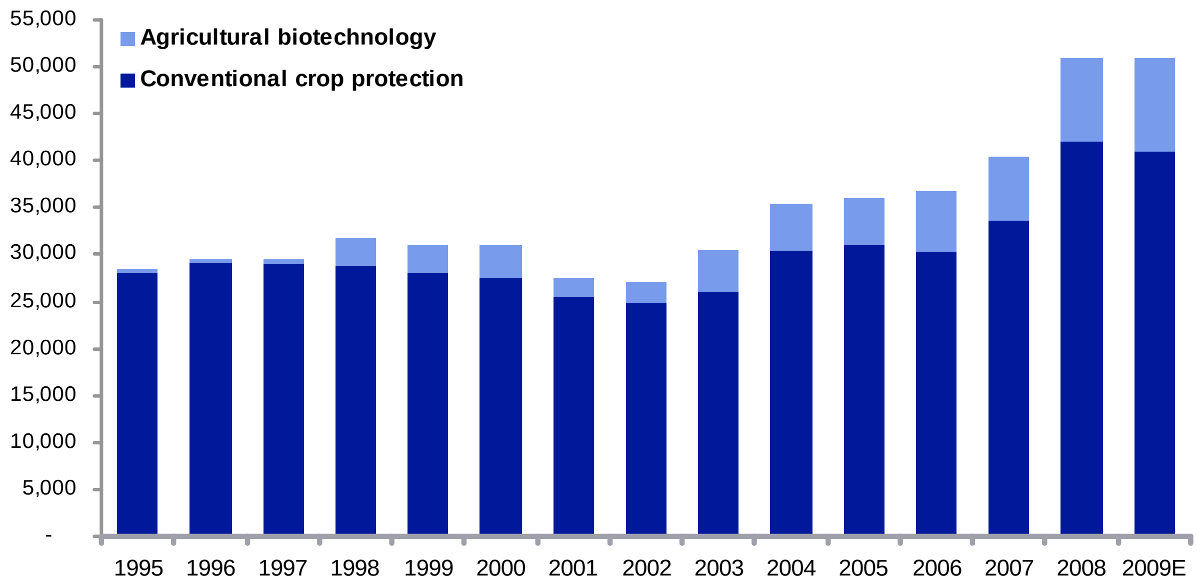
Improve biotech crops and distribution

The traditional breeding of crops has dramatically improved agricultural production over thousands of years. Generating new varieties of crops with desirable traits entails crossing and re-crossing plants over several generations and determining the most advantageous traits for a given set of conditions. Selective breeding, the combination of thousands of genes, in order to achieve some desirable set of traits has also resulted in robust varieties. However, inter-breeding, that is the crossing of totally different species in order to achieve a desired trait, can not happen in nature and is typically not considered an evolutionary pathway (See Box 2). Therefore, scientists have attempted to create desirable traits that don't currently occur in nature, through genetic modification. That is the removal of specific genes from one organism and inserting them into another species. This is referred to as transgenic or genetically modified organism (GMO), or what we call biotech crops. With this method, the desired traits can be evaluated in just one or two generations.

Stronger plant varieties, a key element of raising productivity, have been developed through traditional cross-breeding and through biotechnology. Biotechnology and conventional crop protection have seen significant development in the crop science market over the past two decades (Exhibit 77). In fact, the global area of biotech crops has grown significantly and has reached both the developed and developing worlds (Exhibits 78 and 79). As the acreage grows in biotech crops, so has the value of biotech crops. The forecasted increase in value for 2008-2013 is estimated at 11% compounded growth (Exhibit 80). The development of the crop science market has included herbicides, insecticides, fungicides, biotech and other agro applications (Exhibit 81)

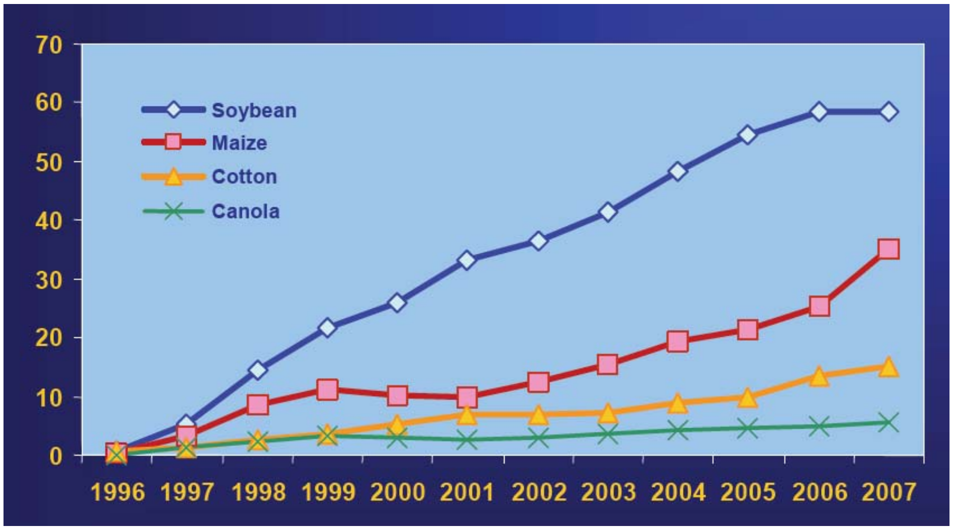
Biotech crops have the potential to contribute to the closing of the production gap through improving yields with lower inputs of water and fertilizers in some cases. Some developed traits can be used to enhance a plants' nutritional value, while others are used to strengthen crops and boost yields by improving plants' built-in resistance to disease, pests or harsh climates. Advances in crop genetics and farming technologies have helped keep pace with growing agricultural demand, and in the years ahead, major exporters like Canada will be expected to bridge a widening gap. For example, biotechnology agreements to jointly develop and commercialize soybeans with improved traits have offered a broad array of products to farmers.

EX 77: Development of Crop Science market (US $ in Millions)



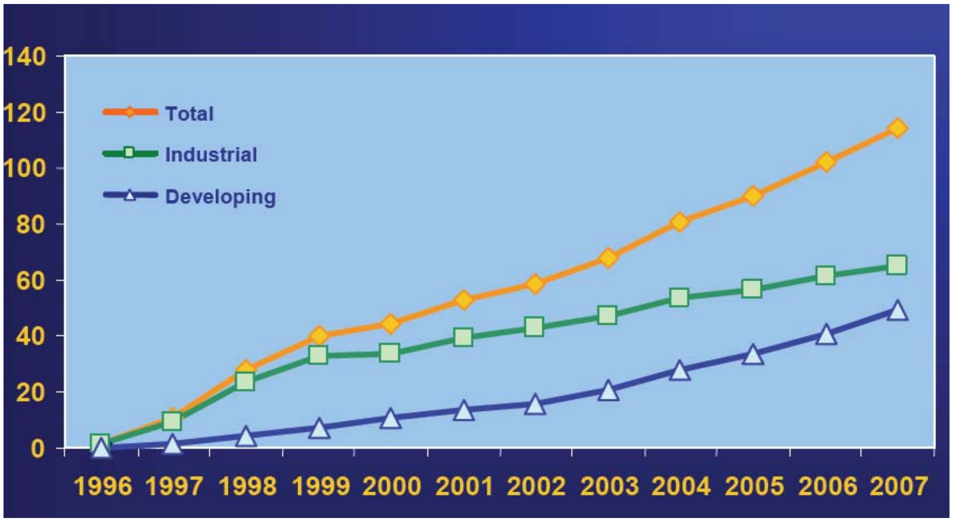
Source. Citigroup Investment Research.

EX 78: Global area of biotech crops, 1996 to 2007: By crop (million hectares)



Source: Clive Jones, 2008.

EX 79: Global area of biotech crops, 1996 to 2007: Industrial and developing countries (million hectares)



Source: Clive Jones, 2008.

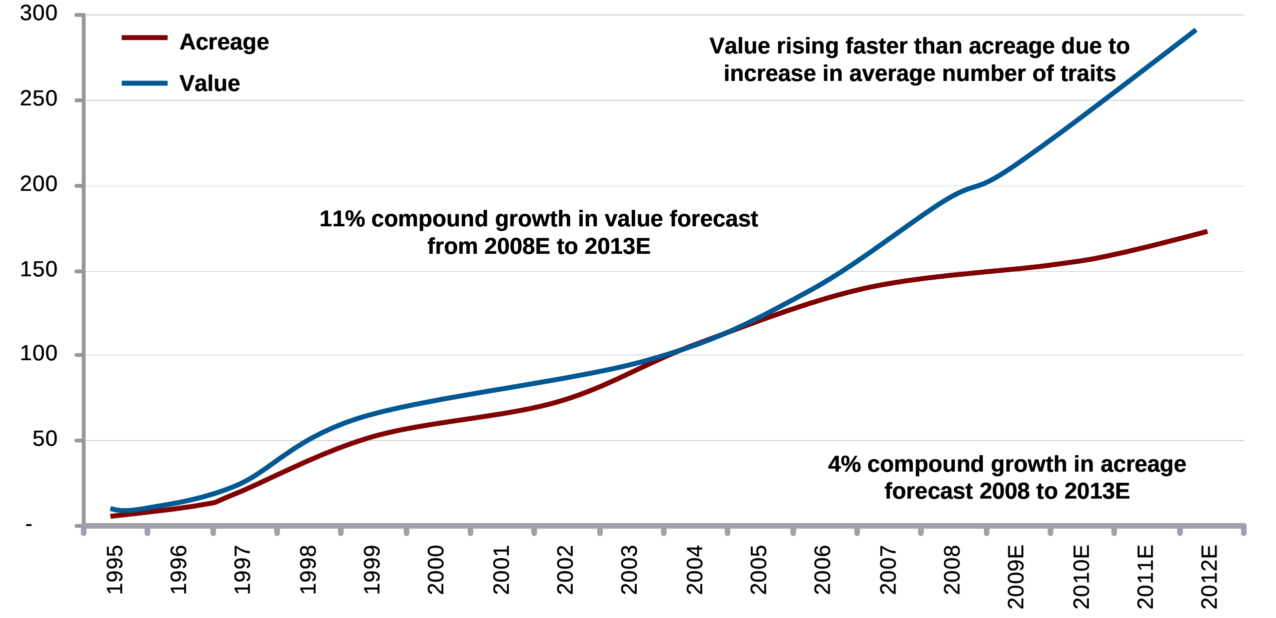
In the case of biotech for biofuels, several companies are pursuing a direct microorganism approach to the breakdown and conversion of plant materials into ethanol. In nature, a live organism "feeds" on plant materials by producing enzymes to convert the plant material into energy for itself. Through genetic engineering techniques, such organisms can be modified to degrade the plant material much faster than normal, and then take the energy released to drive a direct biochemical pathway to biofuel production.

Biotech crops have significant potential to help meet the growing demand for productivity growth. For example, in the US, maize production has increased by 10%, and rice in the Shanghai region of China has increased from 5-15%. However, if GMO crops are used for biofuels and not for consumption by people or animals, then biofuels may be a special application of GMO's. Additionally, before new GMO's are released, they need significant testing to ensure their safety. This is also an area that would benefit from sound governmental policy proposals.

Within biotech crop research, companies are using molecular biology techniques to efficiently and effectively mine the genetic library for useful traits. By combining technologies, such as molecular markers, with other breeding tools, the pace of research can be significantly increased. Major research is focused in the areas of grain yield and quality, pest control, disease resistance, and lipid enhancements to increase the oil and fatty acid contents of crops.

The seed business is not purely aimed at developing its core product. Some companies are pursuing investments in infrastructure, such as warehousing and logistics, which would help to provide horizontal benefits of increased efficiency and reduced costs. In addition, large companies have begun to collaborate on research and development to create streams of successive updates to a family of products in each crop.

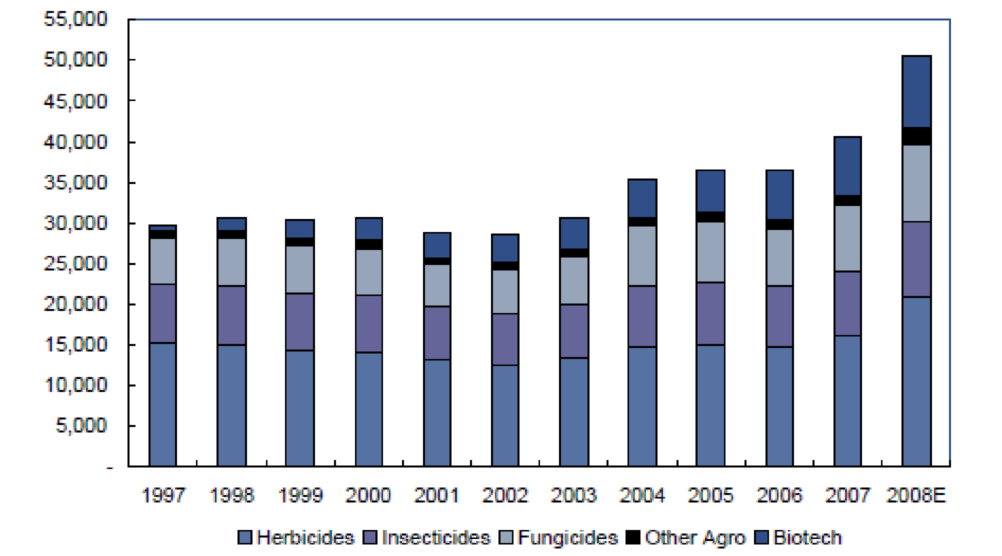
EX 80: Expansion in Value of GMO Market and GMO acreage (2004=100)



Source: Citigroup Investment Research, 2009

Overall, the demand for GMO seed is growing. In the short run, GMO seed and other superior germplasms show significant potential to increase food production. In the medium term, more regions will adopt GMO seed driving demand higher. And in the long term, GMO seed could be a primary driver of higher productivity. Our crop yield patent landscapes are quite divers and illustrate many areas of technology development.

EX 81: Development of Crop science by main product segment (US Dollars in Millions)



Source: Citigroup Investment Research, 2009

Our crop yield patent landscape illustrates where in the industry we are seeing development activity. Over ten years, patent velocity was fairly diversified among DNA and viral genetically-modified crops, as well as mapping and risk technologies (Exhibit 82). In the last five years, the concentration has moved towards efficiency and suppression technologies. Though patent concentration in the last five years is less diversified, there is greater consolidation between technologies (Exhibit 83).

EX 82: Crop Yield 1999-2008: Competitive Patent Landscape Map (392 Patent Documents)

Biotech Crop Options

EX 83: Crop Yield 2004-2008: Competitive Patent Landscape Map (178 Patent Documents)

While the great promise of increased yields, reduced costs and reduced pollution from biotech crops has led to great developments, some studies call in to question the actual achievement of biotech crops. In a recent study by the Union of Concerned Scientists, they concluded that the promise has not yet been met by increased yield, that research and development is very expensive and that the benefits of this research has not reached the poor populations (Gurian-Sherman, 2009). However, as investors, we believe that firms will continue to invest in these technologies and that productivity enhancements, whether through biotech or other low-external input technologies, are critical.

Furthermore, the use of genetically modified organisms (GMOs) in food and animal feed has been met with varying acceptance in different markets. In some markets, most significantly the European Union and Brazil, government regulations limit sales or require labeling of GMO products. GMO's have been met with much enthusiasm for their prospects, but also with controversy due to some environmental and social concerns (Exhibit 84). The promise of increased yields and reduced costs must be met with skepticism until it can be demonstrated in third party documented field trials. Moreover, the advent of the Green Revolution in agriculture, when biotech crops first arrived on the scene, sparked controversy over the problems associated with farmer indebtedness, control over the seed distribution and also the over-producing the capacity of a given landscape causing water scarcity as well as salination of soils.

While the challenges in developing biotech crops require substantial research and development, and a robust regulatory environment, they offer great potential to substantially reduce water and fertilizer inputs, and increase productivity. We acknowledge the sensitivity of this issue and the accompanying complex ethical and social equity issues. And while this remains controversial and often seems to mirror the debate in the power markets around nuclear energy – namely the safety issue, we believe that farmers, markets and governments in many regions faced with the enormity of the agricultural challenge will look at all available options including safe biotechnologies in crop science. This will need to preserve local agricultural resources such as a reserve of biodiverse seed varieties and heirloom crops.

EX 84: Genetically modified foods

Genetically Modified Foods	
Potential Benefits	***Controversies***
Crops - Enhanced taste and quality - Reduced maturation time - Increased nutrients, yields and stress tolerance - Improved resistance to disease, pests and herbicides - New products and growing techniques	**Safety** - Potential human health impacts, including allergies, transfer of antibiotic resistance markers, unknown effects - Potential environmental impacts, including: unintended transfer of transgenes through cross-pollination, unknown effects on other organisms (e.g., soil microbes), and loss of flora and fauna biodiversity -Increased use of herbicids due to weed resistance and also reverting to use of more toxic herbcide
Animals - Increased resistance, productivity, hardiness and feed efficiency - Better yields of meat, eggs and milk - Improved animal health and diagnostic methods	**Access and Intellectual Property** - Domination of world food production by a few companies - Increasing dependence on industralized nations by developing countries - Biopiracy, or foreign exploitation of natural resources -Violation or elimination of traditional seed sharing rights
Environment - "Friendly" bioherbicides and bioinsecticides - Conservation of soil, water and energy - Bioprocessing for forestry products - Better natural waste management - More efficient processing	**Ethics** - Violation of natural organisms' intrinsic values - Tampering with nature by mixing genes among species - Objections to consuming animal genes in plants and vice versa - Stress for animal
Society - Increased food security for growing populations	**Labeling** - Not mandatory in some countries (e.g., United States) - Mixing GM crops with non-GM products confounds labeling attempts
	Society - New advances may be skewed to interests of rich countries - New advances serve needs of private entites only, not societies broadly

Source: The Genome Project, USDOE, 2008

Policy Trends

In addition to agricultural commodity prices, governmental policy can have a strong role in promoting increased productivity. However, agriculture is one of the most restricted markets when it comes to international trade and some misguided policies and lack of investments are leading to underproduction. While the field of agricultural policy is deep and complex and beyond the scope of this report, as investors, we need to be cognizant of how some policies are influencing agri-business.

Primary goals of any agricultural policy must be to protect food security and promote economic development. Recently, food prices were apparently driven higher by the growing demand for biofuels feedstocks. In response, many nations erected trade barriers in the form of export regulations in order to protect their food security, and in the process drove food prices even higher (Exhibit 85). Additional policy responses included reduced cereal import tariffs, export restrictions, food subsidies, price controls, and reduced taxes on domestically produced food. While helpful in the short run, we believe that a free trade scenario will do more to raise productivity and thereby promote agricultural and economic development in emerging economies in the long-run. The global food system should be a free and fair trade system that fosters growing the right crop, on the right soil, in the right climate, with the right technology and management practices, as depicted in our analysis.

EX 85: Global Governmental Policies restricting agricultural exports.

Country	Crop-related export regulations
Argentina	Maize(2006/12-), Wheat/flour(2007/03-): General suspension of approval for export Beef: Export ceiling of 50% of 2005 export volume (on-andoff since 2006) Soybean, dairy product etc: export taxes imposition
Bangladesh	Rice: Ban on export (2008/05-)
Brazil	Rice: Export suspension of government- controlled rice (2008/04-)
Cambodia	Rice: Ban on export (2008/03-)
China	Rice, wheat, maize, soybean, soba etc: Canceled refund of added-value tax (2007/12-) and imposed export tax by 5-25% (2008/01-)
Egypt	Rice: Ban on export (2008/04-)
India	Maize: Ban on export (2008/07-10) Onion: Export license system (2007/10-) Rice: Ban on export (2007/10-) Wheat: Ban on export (2007/09-)
Indonesia	Rice: Ban on export (2008/04-)
Kazakhstan	Wheat: Export suspension (2008/04-)
Nepal	Wheat: Ban on export (2008/04-)
Pakistan	Wheat: Ban on export except governmental contracts (2008/01-)
Russia	Wheat,barley: Imposed export taxes by 10% and 30% each (2007/11-) Wheat: Increased export taxes to 40% (2008/01-) Declared removals of export taxes on wheat and barley in July, 2008
Serbia	Wheat/flour, maize, soybean, etc: General export suspension (2007/08-)
Ukraine	Wheat, maize, barley,rye: Setup of export ceiling (2007/11-) Maize: Removal of export ceiling (2008/04)
Vietnam	Rice: Ban on export except policy in force and governmental contracts (2006/11-). Temporarily released in Jan, 2008, but banned again. Released again in June.

Source: MAFF, Deutsche Securities (Agrochemicals: Emerging tailwind for Japanese agriculture (August 29, 2008))

We also expect the biofuels industry to continue to grow significantly. While it is still being debated and researched, the capacity for biofuels to reduce greenhouse gas emissions must be considered alongside the promotion of biofuels as a means, albeit limited, to achieve energy security. Therefore, including agricultural practices, technologies, and second generation biofuels into the policy for biofuels development is essential. While this development may impact food prices in the short run, the impacts of smart long-term biofuels policy will help raise productivity. To accurately incorporate the costs of carbon emissions in market signals, emerging policy approaches to GHG emissions must be extended to the full life-cycle of biofuels including their net GHG emission or sequestration from land-use change (Fargione et al. 2008). While scientific assessment of land use change issues is urgently needed in order to design policies that prevent unintended consequences from biofuel production, conclusions regarding the GHG emissions effects of biofuels based on speculative, limited land use change modeling may misguide biofuel policy development.

Other policies, such as Renewable Fuel Standards (RFS), which call for increased biofuels in the transportation fuels mix, also impact agricultural demand, although in the US the policy calls for "second generation" solutions from 2015. Exhibit 86 lists several countries that have mandated RFS's and Exhibit 95 lists the RFS Standards for the US until to 2022. However, in responses to the food price crisis of 2008, the European Union has cut its biofuel mandate to 5% from 10% of transport fuel by 2020. This policy may evolve into a low-carbon fuel standard in the future, as the world continues to debate the carbon intensity of the global economy.

EX 86: Voluntary and Mandatory Bioenergy Targets for Transport Fuels in G8+5 Countries

Country/Country Grouping	Targets
Brazil	Mandatory blend of 20-25% ethanol with petrol, minimum blending of 3% biodiesel to diesel by July 2008 and 5% (B5) by end of 2010
Canada	5% renewable content in petrol by 2010 and 2% renewable content in diesel fuel by 2012
China	15% of transport energy needs through use of biofuels by 2020
France	5.75% by 2008, 7% by 2010, 10% by 2015 (voluntary), 10% by 2020 (mandatory EU target)
Germany	5.75% by 2008, 7% by 2010, 10% by 2015 (voluntary), 10% by 2020 (mandatory EU target)
India	Proposed blending mandates of 5-10% for ethanol and 20% for biodiesel
Italy	5.75% by 2010 (mandatory), 10% by 2020 (mandatory EU target)
Japan	500 000 kilolitres, as converted to crude oil by 2010 (voluntary)
UK	5% biofuels by 2010 (mandatory), 10% by 2020 (mandatory EU target)
US	9bn gallons by 2008, rising to 36bn gallons by 2022 (mandatory). Of the 36bn gallons, 21bn to be from advanced biofuels (of which 16bn from cellulosic biofuels)
EU	10% by 2020 (mandatory)

Source: CA Chevruex, 2008

EX 87: US Renewable Fuel Standards from 2007 Energy Act.

Year	Corn Ethanol	Cellulosic	Biodiesel	Other Biofuel*	Total	%YOY
2008	9	0	0	0	9	-
2009	10.5	0	0.5	0.1	11.1	29%
2010	12	0.1	0.65	0.2	12.95	18%
2011	12.6	0.25	0.8	0.3	13.95	9%
2012	13.2	0.5	1	0.5	15.2	11%
2013	13.8	1		1.75	16.55	11%
2014	14.4	1.75		2	18.15	13%
2015	15	3		2.5	20.5	17%
2016	15	4.25		3	22.25	12%
2017	15	5.5		3.5	24	11%
2018	15	7		4	26	11%
2019	15	8.5		4.5	28	10%
2020	15	10.5		4.5	30	11%
2021	15	13.5		4.5	33	14%
2022	15	16		5	36	12%

*Source: EPA * Could include cellulosic ethanol and biodiesel, as well as other biofuels such as biobutanol.*
From: Jefferies Clean Tech Primer.

Policy initiatives that develop infrastructure, such as transport, ports, telecommunications, energy and irrigation facilities; as well as management skills, labor supply and skills to use modern technology such as GPS, will all help raise productivity. Governmental coordination of agricultural research, public, and private partnerships to develop new technologies such as improved seed and crop varieties and water resources management, while often founds in separate policy instruments, has major implications for agricultural productivity. IFPRI estimates that scaling up investments in agricultural innovation will not only help increase productivity but also strengthen the links between public and private enterprises (Exhibit 88). Regardless of the policy formulation, farm commercialization has a good chance of developing the sector and raising productivity. For example, China's recent decision to promote the fertilizer use by direct subsidies to farmers will allow different types of investors to enter and support the development of larger fertilizer circulation firms. Also some governments have restricted the use of genetically modified crops, while others encourage its development.

EX 88: Research needed

Research Needed (by investment size)	Estimated investment ($mn)	People reached
Enhancing yield growth in the context of climate change	127.5	1.18 billion
Scaling up biofortification	125	672 million
Reducing the adverse effects of agriculture on health and improving the health benefits of agriculture for the poor	75	Global impact
Increasing fish production	73.5	32 million
Combining organic and inorganic nutrients for increased crop productivity	55	400 million
Revitalizing yield growth in intensive cereal systems	50	3 billion
Including poor forest people in climate change mitigation opportunities	45	48 million
Addressing threatening pests such as virulent wheat rust	37.5	2.9 billion
Ensuring women's full participation in agricultural innovation	30	200 million
Promoting the sustainable and efficient use of ground water	24	261 million
Promoting innovations to improve small farmer access to trade, market, ad value-chain systems in six countries	10.5	45 million
Tackling cattle diseases such as East Coast Fever	10.5	32+ million
Breeding drought-resistance maize in 20 countries	100	320+ million
Expanding the exchange of genetic resources	15	Global impact
Total	**778.5 million**	**-**

Source: Von Braun, et al. 2008. IFPRI

While governments implement policies for agricultural development, the need for expanding land use must be balanced with protections of forests, marginal lands, water resources and biodiversity. Most of the marginal farm land set aside in the US is in the Conservation Reserve Program (CRP), which has specific environmental goals. It takes highly erodible land out of production to reduce soil erosion and pollution of rivers, streams, and lakes. It has also been credited with significant benefits for wildlife habitat. However, CRP has been criticized as inefficient at protecting water quality due to the focus on specific tracts of land such as riparian areas rather than highly erodible land. If one were to use these CRP lands for perennial feedstocks of second-generation biofuels, there would be little erosion. Once these crops are established they hold the soil in place, and so these lands could be used and still meet the water quality goals. This may be allowed under the 2008 Farm Bill. The environmental goals of these set asides are important, and they may soon be put into biofuels production, as well.

Conclusion

Our global agricultural system has integrated the production of food, feed and fuels. We must raise the productivity of our lands so that all needs can be met and allocate land such that it will allow agricultural production both to feed and fuel our populations. That allocation must be predicated on detailed analysis of current land use, the capacity of given lands under certain constraints, such as water, fertility, and climate, and proper land use policies. While technologies and management practices are proven to raise yields, they are poorly deployed. A lack of investment, misguided agricultural policies and subsidies, and lack of farmer education and training have led to low agricultural productivity in much of the world. As the global population increases, agri-business industries are hard at work solving this challenge.

EX 89: Investment opportunities for closing the yield gap

Investment opportunities for closing the production gap

	Description	Impact	Geography	Type of investment
1	Irrigation	Raises productivity in certain regions	Regional, global	Technology, manufacturing
2	Fertilizer	Raises productivity in certain regions	Regional, global	Technology, manufacturing
3	Machinery	Enable more efficient farming	Local	Engineering, manufacturing
4	Commercialization	Raises productivity in certain regions	Global	Logisitics, manufacturing
5	Infrastructure	Major challenge to agricultural expansion, especially in emerging economies	Global	Governments, engineering
6	Land Expansion	Increase acreage for production	Global	Private lands, public lands
	Biotech Crops	Crop protection, drought resistance, disease resistance, lower water & fertilizer input	Choice by region	Biotech, agronomic

Investment Enablers

	Description	Impact	Geography	Type of investment
1	Education and practices	Adoption of technology and management	Local	Necessary for smaller farmers
2	Policy	Significant impact on agriculture	Global	Necessary for smaller farmers

Source: DBCCA analysis, 2009.

Adaptation, poverty reduction, carbon mitigation and increased productivity can all be achieved in concert with good land use planning. Such technologies as water-efficient irrigation through drip irrigation and agricultural productivity increase through improved soil fertility and preparation and crop breeding and engineering will all contribute to this effort. Additionally, adaptive policies such as water rights, markets to incentivize efficiency, loans and subsidies for technology adoption, capability building in agricultural techniques and research can help us achieve these goals. However, imbalances between supply and demand for agricultural production are growing. The opportunities to close the yield gap are diverse both in terms of geography as well as impact. Each technology represents an investment opportunity for agricultural funds as well as other institutions. Biotech can be controversial but is and will be deployed in some regions. With proper policy guidelines in place that encourage farm commercialization, free markets, and technology adoption, the gap created by growth in food, feed, and biofuel production can be closed.

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