Affordable sensors to support food provision

Bruce Grieve discusses the role of the Syngenta University Innovation Centre at Manchester University in delivering agri-electronics throughout the food supply chain

Creating innovative products and techniques for global farming

This article describes an ongoing open innovation (1, 2) strategy which Syngenta Agribusiness first initiated in 2005. The objective is to enable a step change in farm productivity and crop usage through a fusion of agri-science with non-traditional technologies, such as sensors and informatics. The ultimate aim is to deliver new approaches to food, feed and sustainable fuel supply by:

- Integrating these orthogonal technologies within the existing practices of the company’s core businesses, namely Crop Protection products and Seeds, so as to offer innovative R and D capabilities.
- Delivering novel products and services by packaging the non-traditional technologies alongside the more routine agri-technologies, so as to better service the ultimate needs of farmers and downstream customers.

The need for a step change in agriculture

The motivation for this is manifold. First, and possibly foremost, is the projected growth in world population from 6.5bn in 2006, to 8bn by 2025 and 9.3bn in 2050. Such headline figures are exacerbated by population demographics in the increasingly prosperous developing nations, notably China and India. Another effect of increasing disposable income is the trend towards a high protein, ostensibly, meat diet. To rear poultry for protein, rather than derive it directly from crops, requires around four times the land area in order to deliver the feed volumes. The statistics are even worse for cattle, which require approximately twice as much land area again for the production of feed. In addition to the demands placed on agriculture in feeding a growing populace, the competition for fresh water is having a negative impact on conventional farming practices. Agriculture is the principal user of clean water with around 70% of all rainfall going into irrigation and other farm duties. Figure 1 provides an illustration of this for the Chishtian region of Pakistan. This provides a clear indication of how current farm water consumption will have to be optimised if food production is to continue in the light of competing demands for drinking water and commerce. A third, and related factor, is climate change which is giving rise to more arid environments in some of the world’s most important farming areas. Even those countries which are not forecast to see a reduction in rainfall are not immune, as the unpredictable nature of the weather in intensively-farmed areas means that harvesting cannot be routinely scheduled and may be cancelled altogether if saturated soils prevent farm machinery being deployed. Delayed harvesting often gives rise to crops rotting in the field and so being lost to the food chain. A further secondary effect of climate change is the variability in crop pathogen occurrence and disease spread; a recent example is the UK potato harvest of 2008 where the damp summer resulted in the highest occurrence of potato blight since the Irish Potato Famine of the 1840s.

On top of these global trends is an increasing awareness by national politicians of the importance of securing their own country’s domestic food and fuel supplies (3). In the next couple of decades, numerous governments in the oil-based economies intend to derive substantial volumes of their transport needs from second generation energy crops. As a consequence, yields from existing arable land must increase by 50% if the current 400M hectares of Amazonian rain forest are to be protected. Historically, Latin America has provided for the shortfall in food for Asia, however, this is unlikely to be sustainable in the future. Given this context, the worldwide implications for farming dictate that radical changes have to occur to avoid devastation. This view is supported by Professor John Beddington, the UK Government Chief Scientist, who recently commented: “The agriculture industry needs to double its food production, using less water than today ... The food crisis will bite more quickly than climate change” (4). The technology opportunities for sensors in food and farming were then expanded upon by Professor Beddington in this very journal (5). It is this background that has driven Syngenta to take a prescient position...

![Figure 1. Water usage profile – Chishtian region of Pakistan (Source: Cook and Woolley, ‘CGIAR Challenge Program on Water and Food’ – www.waterandfood.org).](image-url)
and seek partnerships with academic groups and companies normally
alien to the biotechnology sector. The University Innovation Centre concept
is one element of this research strategy.

**The changing nature of agribusiness**

During the 1990s, the chemical
production sector in Europe and North America saw considerable upheaval as
the business models tended to migrate from one of having large multinational
conglomerates with highly integrated
and interdependent business units
to one of large numbers of divested
specialised companies aimed at meeting
the needs of a specific customer group.
The agri-sector was no exception to this
and is now dominated by just six global
businesses, between them covering
over two-thirds of the world’s farm
production. The formation of Syngenta
from a number of parent businesses has
parallels across a number of the majors
in the sector, as depicted in Fig. 2.
This chart also illustrates the limited
remaining freedom in the agri-
sector for major company mergers
without the infringement of anti-
competition laws. As a result, further
cosmetic growth in these businesses
will be dominated by a need to grow
organically through the introduction of
innovative new products and research
techniques rather than mergers and
acquisitions.

**The wireless sensors revolution**

The ever increasing access to
information on the move, from a
combination of low-cost electronics,
wireless telemetry and novel sensor
science, has already changed the way
we shop for goods, travel around,
communicate with colleagues or spend
our leisure time. This revolution
is set to continue apace as micro-
and nano-engineering are merged with
information science and inexpensive
printable plastic semiconductors.
These changes have been catalysed by
a number of circumstances, which are
mostly unrelated to the agricultural
sector. Examples include the USA’s
‘Enhanced-911’ phone capability,
which embeds a new generation of
low cost GPS receivers within
mobile phone handsets to pinpoint
the location of a call made to the
emergency services. Such systems
are rapidly increasing the availability
of cost effective wireless-enabled
positioning technology that may act as
a platform for sensing systems. Again
in the USA, the supermarket chain
Wall-Mart has dictated to its top 100
suppliers that they must provide Radio
Frequency Identification (RFID) tags
on all their inventory. Existing tags
are too expensive to meet this need
without increasing costs to supermarket
consumers so the industry is moving
towards printable polymer electronics
in an attempt to hit the goal of a sub
1 cent tag. Such circuit techniques
may then be used to form disposable
sensor platforms for ‘smart item’
tagging and other duties. The growth
in portable computing has also given
rise to the ubiquitous availability in
homes, businesses and cities of RF
bandwidth with direct access to internet
portals. In addition to the development
of the new generations of electronic
hardware, there is a matching increase
in device intelligence (6). Closer to
the agricultural sector, dramatic reductions
in gene mapping costs are allowing
scientists to examine the methods by
which parasites detect their hosts and
to emulate these within sensor systems.
From this background, agriculture is
equally well placed to take advantage
of the sensors, electronics and information
revolution as other customer-driven
sectors. The lack of strategic take up of
these agri-electronics technologies by
any of the major agri-science businesses
can be seen as an opportunity rather
than a hindrance.

**Charting the landscape for agri-electronics in global farming and food supply**

In order for a biotech business to
take advantage of sensing and
informatics, it is necessary to set into
context how such systems may offer
beneﬁts to the food and farming
sector. Syngenta has adopted a highly
structured landscaping approach to
scope out the opportunities from a
number of enabling technologies, of
which sensing is one. These landscapes
cast an orthogonal impact on the agri-sector over
a 5-15 year horizon when merged
with the products and activities of the company’s
existing mainstream business units. Details of the
landscaping approach cannot be covered within this short article,
sufﬁce to say that the methodology draws
upon business experts and scientists,
from within the company and outside,
and create a map which is very different
from anything that would be produced
from teams working in isolation. The
Sensors Landscape was compiled in
May 2007 and is a reﬂection of the
opportunities offered at that snapshot
in time. However, by virtue of the
landscaping technique, it is possible to
quickly revisit the rationale behind each
step on the map and update it as new
business or technology opportunities emerge.
The University Innovation Centre concept

The Sensors Landscape gives a picture of what could be achieved; however, this is of little benefit unless there is an appropriate route to develop the required systems. At the one extreme, the launching of an in-house agri-electronics design team is a possibility but this approach has a number of limitations, notably the lead-time and costs of recruiting skilled personnel as well as maintaining a suitably sized group and associated infrastructure. At the other extreme is the intelligent purchaser model, whereby the necessary systems are acquired from third parties such that they meet an agreed specification. This has some superficial appeal for those applications where a clear market demand can be defined for existing electronic systems which are currently almost capable of doing the duty.

These types of potential products are few and far between as such obvious exemplars will typically have been previously exploited. The intelligent purchaser approach is also deficient for introducing truly novel technologies as blindly following market-pull is unlikely to make the necessary linkages between the status quo and the future possibilities. This may be summarised by the phrase; ‘how can you buy a technology that does not exist to enable a market that is not currently possible’.

The University Innovation Centre (UIC) model, ultimately adopted by Syngenta, addresses these issues by adapting an open innovation approach similar to that pioneered by Rolls Royce, the aerospace company, and their University Technology Centres (UTCs). The Syngenta concept has parallels to the UTCs in having ring-fenced academics tasked with delivering the medium-term proof-of-concept technologies, via direct business funding, and the related longer-term underpinning sciences, via grant proposals in partnership with the Research Councils. Where the critical difference lies is in the scope of the technologies addressed. Unlike the UTCs, which are designed to replace and enhance previous in-house core capabilities, the Syngenta concept is to use the Centres to identify and deliver technologies which are currently not core to the business and may never be core. The rationale is that these UICs will provide the technology platforms that can then yield research methods or complementary systems for integration with the existing mainstream products and practices.

The competitive advantage offered by this approach is not dependant upon Syngenta manufacturing the systems arising from the UICs. Instead, the model is that the UICs work alongside the company’s business development teams to identify the markets that can be opened up by having access to hitherto unavailable enabling technologies. They then deliver the prototypes for verification in field trials and at that point handover the now proven technologies under a Syngenta University license to third party device manufacturing companies. In this way, Syngenta may then globally source appropriately engineered commercial systems and the UICs can move on to their next projects.

The first Syngenta UIC was launched at the University of Manchester in late 2007 and is focused on the delivery of sensors and agri-electronics. The choice of Manchester for this initial UIC was strongly influenced by the merger of the Victoria University of Manchester and UMIST in 2005.

Delivering agri-electronics for future food and crop supply

Since its inception, the Sensors UIC at Manchester has gradually started to populate the Landscape map with medium-term specific projects addressing such area as:

- “Farm-to-fork” management of wastage in the perishable goods supply chain by fusing plant genetics and crop input data with package level remote sensing of produce stress.
- In-field ‘sentinel’ sensors for monitoring the earliest phases of disease ingress allowing crop protection products to be prescribed and targeted with surgical precision.
- Wide area subsoil phenotype imaging for accelerated isolation of genetic traits in the breeding of climate tolerant crops.
- In-process enzyme sensing for efficient processing of second generation fuel crops.

The next phase in this agri-electronic evolution is to integrate affordable in-farm biosensing of fruits and vegetables with the downstream needs of food processors. In this way, greater productivity and reduced energy usage and wastage may be achieved by increased raw material uniformity and enabling more tolerant production. This will need a true partnership between companies across the food supply chain. Notably, the processing of high-value crops such as potatoes and tomatoes are seen as ripe for this approach. Such thinking will require a fusion of agri-business strategy with food science and technology. This will be the next goal for the Sensors UIC and industrial partners.

References


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