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GNSS Applications in Cropping Agriculture using Controlled Traffic Farming.

Dr Don Yule
CTF Solutions, Australia
0427113127, don@ctfsolutions.com.au
Tim Neale (2)
CTF Solutions, Australia
0428157208, tim@ctfsolutions.com.au
Dr Jeff Tullberg (3)
CTF Solutions, Australia
0417134372, jeff@ctfsolutions.com.au

ABSTRACT

Controlled Traffic Farming (CTF) is a proven platform for profitable and sustainable cropping in the grains, cotton and sugar industries. CTF also provides continuous improvement opportunities through applications of new technologies, particularly GNSS, remote sensing and GIS.

CTF is an innovative farming system incorporating permanent wheel tracks (controlled traffic), zero tillage, property and layout planning, best agronomy, record keeping and minimum environmental impacts.

GNSS provide accurate location and records of farming operations with enormous implications. This links seamlessly with CTF's ability to spatially manage all farming operations.

CTF reduces soil compaction; manages runoff, erosion and waterlogging; increases farm efficiencies; and reduces time to farm. GNSS location and repeatability provide accuracies to allow inter-row management to 2cm with massive machines up to 30m wide (for planting, herbicides, fertiliser and fungicides) and automated steering, input applications, and recording systems. This is all based on our ability to conduct one operation in very close relation to previous or future operations. Examples will be presented of planting, spraying, harvesting, resource management, and record keeping.

Increasingly, this combination of CTF and GNSS is adding value to other technologies including satellite imagery, topographic mapping and GIS analyses, particularly for defining causes and management of paddock variability. Examples will be presented of forensic agronomy (what are the causes?) and farm/farmer R&D (farmer conducted on-farm research using these tools).

KEYWORDS: Agriculture, CTF, GNSS, applications, innovation.

1. INTRODUCTION

The paper briefly reviews the basics of CTF and the benefits for farming systems, and GNSS applications in agriculture and their value in CTF systems. The paper examines the platform created by CTF to improve the triple bottom line and the complementary use of GNSS and related tools to provide the next steps for CTF. this combination of CTF and GNSS is adding value to other technologies including satellite imagery, topographic mapping and GIS analyses, particularly for defining causes and management of paddock variability. Examples will be presented of forensic agronomy (what are the causes?) and farm/farmer R&D (farmer conducted on-farm research using these tools).

Highlights include understanding productivity drivers, causes of variability and management opportunities; automated record keeping and measure to manage; on-farm R&D for system improvement; and building partnerships for achieving goals.

2. THE BASICS OF CTF

CTF specifically recognises that cropping is mechanised, wheel compaction is good for wheeltracks but bad for crop growth and wheeltracks are spatially distributed.

The Basics of the CTF system defined by our experience so far are:

1. Property management planning. The PMP is based on natural resource identification and suitability, goals and needs analysis, and infrastructure.
2. Designed paddock and farm layouts for water management and infrastructure. Paddock layouts consider surface water flow and drainage, waterlogging, soil types and properties, wind direction and erosion, access and efficient transport, and logistics.
3. Controlled traffic or permanent wheeltracks to manage compaction, increase infiltration, and provide access and timeliness, accuracy and efficiency. All tractor and harvester wheels are on defined wheel tracks. Wheel tracks are typically 3 m wide (to suit the harvester). Low cost machinery modifications are available.
4. Matching machinery and auto-steer = precision. Machinery should be reduced to planter, sprayer and harvester with chaser bin. 9, 11 and 12 m units are grain options. 2cm RTK GNSS auto-steer is recommended, particularly for marking at planting.
5. High cover levels - zero tillage. Controlled traffic makes accurate, efficient, effective and flexible herbicide applications possible.
6. Farmer/adviser/supplier partnerships – a team approach. Each farmer/farm combination is unique. CTF systems are developed through partnerships between land managers and technical advisers.
7. Measure to manage for continuous improvement, record keeping, on-farm R&D and problem solving. Many new technologies are available, and they all work better with CTF.

The theme of this paper is **“everything works better with CTF.”**

The farming system impacts from these few basics all seem to be positive.

- Optimum resource allocation and use – natural and purchased
- Natural resource quality, manage resource degradation (compaction, water and wind erosion, waterlogging, deep drainage and salinity)
- Access, efficiency, effectiveness, flexibility and most of all timeliness
- Precise row, inter-row, wheeltrack management
- Higher water availability and crop water use, i.e. productivity
- Opportunities for dynamic, innovative management and continuous improvement.

In summary, CTF is a comprehensive and strategic systems approach; it is aimed at sustainability; it is triple bottom line; and it provides the essential spatial framework for most new technologies. We have CTF solutions for grain, cotton and cane, horticulture is still a challenge. The challenges for CTF are to achieve maximum profitability (how to maximise our NRM and machinery) and maximum performance and personal benefits (automated record-keeping with appropriate processing, reporting and actions).

3. APPLYING THE BASICS

Improved agronomy. CTF improves the soil physical and chemical fertility and our agronomy must use this to produce higher yields and increased incomes. Soil water relations are optimised, the fundamental driver of dryland farming. Much on-farm research is needed to determine how best to farm the non-degraded soils that CTF produces. Machinery issues are critical.

Auto–steer, 2 cm GNSS. Growers with auto-steer report that this was the best investment they ever made. With CORS networks and much reduced prices, RTK auto-steer is now a must, the first investment to make in CTF, for accuracy, reduced driver fatigue and all drivers perform equally well.

On-farm R&D. The controlled traffic system with yield mapping facilitates strip experiments. Grower managed trials within the farming system ensure that results are applicable and quickly adopted.

GIS computer based farm record systems. CTF systems support automatic recording of farm operations and measurements, and incorporation of all information into a GIS based system for all spatial data.

Use remote sensing. Remote sensing such as multi-spectral aerial or satellite imagery offers cost effective, high resolution data to measure farm performance and responses to treatments. It links with yield monitoring and the spatial accuracy of CTF and does not interfere with farm operations.

Use efficiencies as performance indicators. Efficiencies reduce the year to year and season to season variability. Measures such as water use efficiency, machinery efficiency, and financial efficiency are useful.

4. GNSS AND RELATED TOOLS

GNSS and related tools are digital, spatial, temporal and measure something (collect data). Three-dimensional spatial accuracy from GNSS is critical for location to overlay other data, and for topography to design farm layouts.

Typical sensors measure yield, spectra, radiation, electrical properties, etc. The most common spectral data are multi-spectral – colours, infrared, thermal, etc. and now hyper-spectral are available. Radiation (gamma, magnetics and radar) is widely used in geology. Electro-magnetic induction (EMI) is an example of electrical properties. These sensors provide information about landscapes, soils and crops and their spatial distribution.

Other important measurements, e.g. soil sample analyses and soil water, salt and pH are not well suited to spatial collection, the pixel size could be 100,000m^2.

These tools are used to define and manage variability in crop growth, maturity and quality. Management options depend on the scale of definition. We manage wheel tracks, inter-row and rows with high resolution data; and soil types and management zones with coarse resolution data. Management should be based on understanding causes.

Paddocks are managed uniformly, e.g. planting, spraying and harvest. Reducing variability is important, e.g. from machinery or waterlogging. Creating variability is bad, e.g. with contour banks, land leveling, roads and fences, and variable fertiliser inputs.

Successful spatial tools include:

- Imagery. High resolution imagery is the powerhouse of tools, it can provide digital, spatial, temporal data from a range of sensors at low cost. Imagery can be satellite, aerial or proximal; each has a place depending largely on the area of interest. Each can deliver 1m^2 pixels or less. These sensors are in-direct measures of yield and biomass and the value must be evaluated.
- Yield monitors are the most basic measure of farm performance. Data quality depends on having a full comb all the time to ensure reliable and credible data. Yield maps should be "ground truthed" each season to remove known errors. Pixel size is about 400m^2.
- Topography. With RTK GNSS, topography to 5cm resolution can be collected at a reasonable cost and growers can collect their own data. Topography is essential data for farm layout design and for waterlogging and erosion management. Topography is often related to soil types and an indicator of soil distributions. Topography pixels are about 200m^2.
- GNSS location. The location log records where you are and where you have been when. These data are useful in GIS analyses to link measured effects to prior actions.
- Soil properties. These include EMI which measures electrical properties related to clay, water and salt content at a pixel size about 200m^2.
- GIS Tools. For data management and record keeping, for analyses and relationships among data layers, for identifying causes of variability, and for reporting as maps and graphs. These are powerful tools but they depend on the quality of the data. If the data is variable, statistics can be used. This will hide the variability we want to understand and repair.

5. LINKING CTF AND GNSS TOOLS

With RTK GNSS, CTF imposes a defined spatial distribution on farm machinery activities, and defines variability by where it is and what caused it, e.g. wheel compaction. CTF ensures that one operation can be carried out in exact relation to past or future operations. CTF ensures quality data from yield monitors and the value of GIS analyses. When CTF is designed to reduce variability caused by waterlogging, erosion, compaction, fences and rocks, crops grow more uniformly and spatial tools work better. CTF supports collection of spatial, digital data in computer ready formats.

Imagery at small pixels is a key linkage with CTF because CTF aims to manage variability at this scale, e.g. wheel track compaction, row and inter-row management.

Imagery is also a proven agent of change. It shows what farmers know but in a way that can be understood and acted upon. Solutions become obvious. It is possible to drain low spots or move rock heaps, because then CTF will work much better. The driver of this change is the partnership between grower and adviser asking "what can we do with this information?". Many growers say "you have shown me what I already know", but "If you know everything, it's very hard to move forward".

Yield monitors. CTF allows automated analysis of yield data, only the headlands are "fuzzy". The data can be used with confidence. Yield maps no longer need to be stored for 5 years to find some consistency in the "fuzz".

Topography data are crucial for CTF layouts and identify solutions to waterlogging and drainage issues. The links to landscape properties and soil types are useful.

Pixel size. Previous work harvesting single rows of crop identified large variability across the planter and due to wheel tracks. This led us to imagery with pixel sizes of $1m^2$, which has further identified a wide range of variability associated with random traffic, poor machinery performance, paddock histories and layouts, erosion and waterlogging, and weeds, pests and diseases. The causes were identified from the spatial distribution of the variability combined with the knowledge of the grower. This variability is caused by grower management and our priority is to reduce and manage it.

The common Precision Agriculture approach is to define management zones based on coarse data sets – yield monitors, EMI and Landsat imagery. The pixel size is greater than $200m^2$ and at this scale the variability and causes described above are not obvious. Management zones are typically related to soil types and landscapes, and managed by variable rate inputs.

GIS. High quality data, provided by CTF, maximises the value of GIS and the confidence in the outputs. This should allow automated data processing, rapid reporting back to growers and in-depth analysis. Undoubtedly, handling the increasing volumes of data and information (we call this Information Rich Agriculture) is difficult with deficiencies in both software and support services.

Site Specific Management. The accurate positioning of CTF and GNSS allow management at very specific locations. Examples include inter-row management for stubble handling, weed control, fertiliser application; row management for pest and disease control, and foliar sprays; and wheel track management for weeds and compaction. Precise management also applies to layouts for drainage and runoff control.

6. USING SPATIAL TOOLS TO MAXIMISE CTF

The CTF goals are to maximise the efficiencies and effectiveness of farming systems by:

- Maximising the quality and use of both natural and purchased resources. CTF with GNSS creates the platform but there is an enormous job to achieve adoption across industries and to train and maintain support services.

- Measure to manage and reduce variability. CTF provides the system and spatial tools provide the data, processing and presentation. This combination is the basis of "forensic agronomy" – how we identify problems, causes and solutions (see below).
- Measure to market. CTF with GNSS should be marketed as a sustainable, environmentally friendly farming system, and spatial tools provide marketing information.
- Continuous improvement through new approaches to on-farm R&D (see below).
- Cooperation with independence. Spatial tools support cooperation among growers, e.g. shared reference stations and satellite imagery. IGNSS members and CTF Solutions are cooperating, and the Australian Controlled Traffic Farming Association was formed in 2006 to support wide cooperation on adoption, marketing and R&D needs. There are many shared issues and more cooperation will produce mutual benefits.

6.1 Forensic agronomy

Forensic agronomy aims to find the causes of problems in farming system. Spatial tools in a CTF/GNSS system allow in-depth analysis of crop and soil responses that can frequently identify both the causes of variability and possible solutions.

At 1-4 m^2 pixel scales waterlogging and erosion can be clearly identified and options identified with topography data; machinery performance is also obvious (compaction, overlaps, misses, inefficiency, trees and rock heaps); insect and disease damage quantified; responses to inputs (lime, fertiliser, manures, etc.) quantified. This remote sensing provides a new dimension to crop management.

High resolution data also add value to coarse data layers such as yield monitoring and Landsat imagery. GIS skills are essential, analysis is slow and involves large amounts of information. Automated analysis is needed in the future but there are many challenges. This is a new concept and a future direction for us.

6.2 Farm/farmer R&D.

The CTF/GNSS platform and the measurement capabilities of spatial tools offer a new way to do on-farm research. Using strip trials as the basic approach, farmer/adviser teams can design, implement, measure and interpret a wide range of experiments. The basic unit is a planter or sprayer/spreader width, and treatments are realistically large and practical within the farming system. With a GNSS controller, the plan is loaded in and farming operations continue as usual. Plots are automatically marked in the computer. Treatments related to any input are possible but also new crops, rotations, etc. Rate trials would be standard.

Crop responses are measured spatially with imagery and yield monitors, at data intensities far greater than research plots, e.g. IKONOS satellite imagery at 1m^2 pixels (10,000 values/hectare). Sensors can also measure temporal changes. The opportunity exists to analyse the data as treatment means and as response curves related to the background paddock variability measured in control strips.

This approach requires considerable development. The farmer /adviser team involves new skills and roles, planning needs are new, implementation should be straight-forward but new analysis and interpretation methods are needed. The adviser role requires new applications of R&D skills and close partnerships with growers. Other technical support may be required.

7. CONCLUSION

Cropping agriculture brings a wide range of new applications to GNSS and GNSS provides a platform for new applications in agriculture. Further cooperation between the industries will have large mutual benefits.