Controlled Traffic Farming takes Conservation Agriculture into China

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INTRODUCTION

Soil compaction, a form of land degradation, is widespread in cropping lands and occurs largely as a result of random field wheelings and land preparation from agricultural machinery. According to Whalley, *et al.* (1995), the processes of machinery and tillage are often disruptive and harmful to soil ecosystems. The use of tillage to remove compaction can be expensive, not only in terms of the increased power requirement, but also in terms of fuel usage (Tullberg, 1998). Compaction is cyclic under conventional farming systems and is persistent (Alakukku, 1998). According to Brussaard and van Faassen (1994) understanding of soil amelioration by natural process is required to optimise farming processes. Most clay soils are very susceptible to soil degradation, but it is widely believed that they can regenerate, effectively breaking up compaction. However this is only true if cyclic compaction from random traffic is removed. Controlled traffic farming systems (CTFS) have been widely adopted in Australia, primarily to reduce the effects of compaction, but its adoption also has a number of other benefits. Such as facilitating zero tillage, stubble management, irrigation management and reducing farming inputs. Until recently very few studies had looked closely at what happens to a degraded soil environment when traffic and tillage is removed. Even more recently others have demonstrated that soil compaction significantly influences soil hydraulic properties, reducing the saturated hydraulic conductivity and alters the shape of the soil water retention curves (Zhang, 2006).

In terms of amelioration, people have only thought of tillage effects, and not traffic removal and its effects on soils and processes. Traditional farming systems in the People's Republic of China (PRC) are characterised by routine cultivation (mouldboard ploughs and rotary hoes) and removal of crop residues from the field (for animal fodder and household fuel). Pressure on the farming lands of the PRC to maintain productivity has been increasing at a phenomenal rate, to support the current national population of 1300 million (with an estimated annual increase of 4 million) and the fastest growing economy (10% per annum) of any major world country. This pressure, in association with the harsh cultivation and residue removal regime, has led to severe land degradation, contributing to the PRC's unenviable status of having "among the most severe (environmental) problems of any major country" (Jared Diamond, 2005; "Collapse – How Societies Decide to Fail or Survive"). Especially affected are the PRC's dryland areas, which occupy 52% of the nation's total area with 43% of the PRC's population. These lands are inherently fragile due to a combination of harsh seasonal variations in climate, inherently low soil fertility, annual rainfall of less than 500 mm and years of severe drought.

The PRC government and the Chinese people have been most aware of the growing land degradation issues and have been actively creating several farmland-based approaches to combat desertification and erosion. A vital approach is CA. CA is a further development of the practices commonly termed Conservation Tillage (CT). CT is defined as "all conservative farm practices that leave a minimum of 30% of (crop) organic residues in the field". In contrast the key elements of CA are: zero (or reduced) tillage, careful management of residues, and the use of cover and rotation crops to maintain ground cover, increase organic carbon and soil biodiversity and minimise crop diseases, a balanced application of chemical inputs (only as required for improved soil quality and healthy crop and animal production), and the precise application of all inputs, including maintaining permanent wheel tracks for all in-field equipment, and the precise application of pesticides, fertilisers and weedicide. Each of these elements are important in there own right. However, the “power” of the CA system is gained, not from focusing on any one element to solve a specific limitation, but rather from the synergy (interplay) of the various elements. In this way, multiple benefits of CA are gained from an integrated approach from the farm to the ecosystem level.

The aim of this study was to assess changes in soil following the implementation of a controlled traffic-zero till farming system after 100 years of conventional farming and then in subsequent years apply that understanding to high altitude arid farming regions of North western China. This technology transfer would introduce conservation agriculture (CA), by using practises such as zero tillage and permanent raised beds (PRB), to reduce irrigation water use, maintain farm yields and improve farmer incomes because long-term simulations have shown that soil management strongly influences the magnitude of the water balance components.

METHODOLOGY

An Australian study was conducted on structurally degraded black cracking clay, which had been cropped conventionally since 1945 in the Lockyer Valley, Queensland to demonstrate the natural regeneration of soils and the impact of traffic removal. A CTFS was established on 3m wheel centres, in four, 80 by 12m blocks. Three tracks in each block were either wheeled once, twice or three times at planting and harvest. After each planting, over four seasons, soil measurements and observations were made in track and cropping zones. Rate and depth of soil amelioration from biological activity of previous cropping seasons was assessed by changes in hydraulic conductivity (K_s) and plant available water capacity (PAWC).

RESULTS AND DISCUSSION

At the start of the study K_s was very low in comparison to well structured Vertosols. After 7 months of nil traffic K_s increased by 60%. After 22 months K_s increased 4 fold at 100mm below planting depth to $125mm.h^{-1}$, with 200 and 300mm depths increasing by $50mm.h^{-1}$ on initial values. Track zone conductivities remained constant ($\sim22mm.h^{-1}$) over the four cropping seasons (Figure 1).

Under conventional tillage conditions field capacity was measured at $0.36g.g^{-1}$ and after 22 months of nil traffic it increased by 7% to $\sim0.39g.g^{-1}$. Moisture content at wilting point improved by 6.5% after 22 months of nil traffic changing on average over the 0.3m depth from $0.29g.g^{-1}$ to $0.267g.g^{-1}$. PAWC was less than 10mm per 100mm depth of active rooting zone under conventional tillage conditions. However, after 22 months of nil traffic, PAWC increased by 63% to >15.9mm per 100mm depth of active rooting zone. Track zones PAWC remained constant at <10mm per 100mm in the top 400mm of soil (Figure 2).

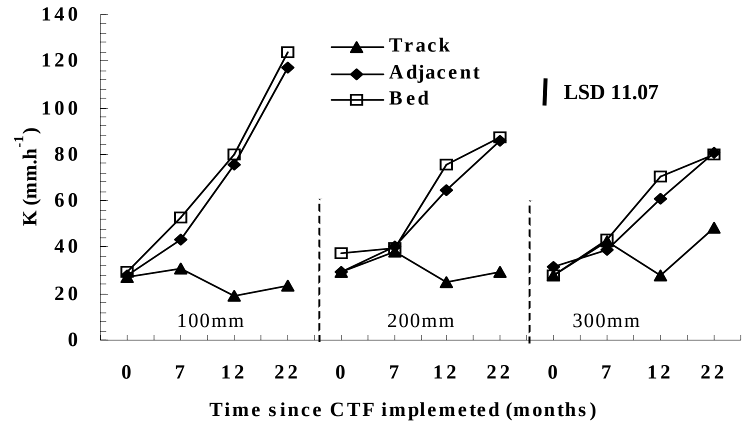

Figure 1. The average unsaturated hydraulic conductivity of the soil matrix (K_{matrix} $mm.h^{-1}$) grouped by depths and position for months after nil traffic (after implementation of CTF) through four seasons.

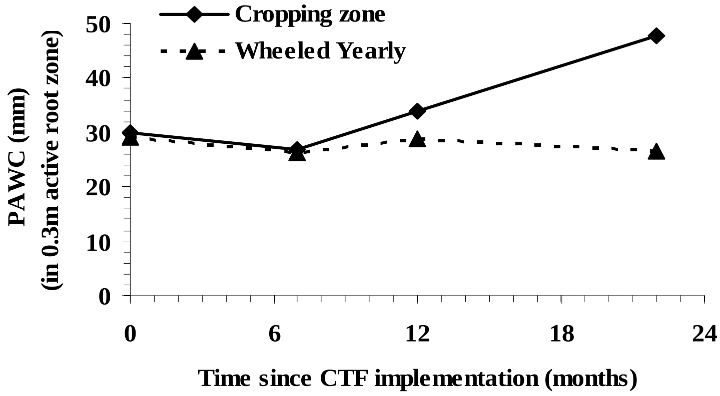

Figure 2. The change in PAWC (mm) in 0.3m of active root zone for the cropping and wheeled zone after 22 months of controlled traffic farming on an area previously cropped conventionally (random traffic).

The change in hydraulic conductivity and PAWC indicated movement away from a soil profile with a predominance of micropores (<30μm) to include a range of larger transmission pores up to 350μm over the period of the study. Development of micro cracks, larger planar voids and biopores formed by drying processes persist in non-wheeled soil, increasing pore interconnectivity and pore size distribution. Seasonal improvements in soil structure accrued and expanded down through the profile. However the rate of change was very dependent on cropping zone ageing processes since the last tillage/traffic event. Initially any changes in structure due to reduction or absence of tillage and traffic were small because it remained difficult for roots to penetrate the soil. Once a few roots penetrated and effects of drying accrued, and the natural cycle of amelioration proceeded. The better the drying, the better the structural improvements, the better the root environment and quickly the entire biological and physical systems interact, moving toward the soils natural structure. However based on this study data, to naturally ameliorate the soil from a degraded state to a condition, that is, halfway toward a non-degraded clay soil, could take 5-9 years. However even over the short study period the transitory nature of tillage was demonstrated and even the soil moisture characteristic can be affected by agronomic management.

Significant gains in production can be made by zero till CTFS through increased pore interconnectivity, pore size distribution and oxygen status. The improvement in soil structure and subsequent increase in productivity is based on the integration of four elements, controlled traffic, zero till, organic matter improvements and soil inspection. In comparison to conventional cropping practices this approach leads to a lower input self-sustaining farm management system.

SUMMARY

Soil amelioration in the cropping zone was evident after 3 years of isolation from wheel traffic. This was demonstrated by:

a. Hydraulic conductivity increased by 65% (all layers 0-400mm).
b. PAWC increased from 9-16mm per 100mm of active root zone in top 400mm.

This study has demonstrated the effectiveness of natural amelioration when the unique properties of Vertosols can be harnessed via controlled traffic zero tillage farming systems. Under conventional (random traffic) farming operations, this level of amelioration may be achieved at considerable cost by soil amendments and intensive tillage, but the results are often transitory and is inadequate for a self-sustaining cropping system. Taking a simplistic view of controlled traffic farming systems, amelioration is achieved at no extra cost and offers an opportunity for improving the productivity and sustainability of mechanised cropping.

INTRODUCTION OF CONSERVATION AGRICULTURE TO CHINA

Gansu is a north western Chinese province in the yellow river upper drainage basin and between Gansu and neighbouring Inner Mongolia lays a distinct valley, the Hexi (*Her She*) Corridor.

In the past (~4000 years), reliable snowmelt water from the adjacent Qialian (*chil lian*) mountains has sustained the irrigated agricultural areas along the length of the valley. In more recent times (last 30 years), reduced snowmelt water has led to significant reductions in available surface water, whilst over extraction and decreased recharge has lowered water tables in groundwater driven systems. As a consequence, severe water restrictions are being placed on farmers (up to 50% reduction in allocations). Although delivery losses are being reduced, through better channel lining, few practical solutions are being offered to farmers to cope with the policy driven cutbacks in water allocations, water price increases, pumping costs and the demand for food. Other crop production issues associated with water restrictions, such as small farms, low levels of mechanisation, high inputs, conventional tillage, high wind erosion, soil degradation, low incomes and the loss of young men to the cities, are placing further pressure on farmer livelihoods. Therefore the aim of this project is to introduce and develop conservation agriculture using practises such as, zero tillage and permanent raised beds (PRB), to reduce irrigation water use and wind erosion, maintain farm yields and improve farmer incomes.

Preliminary studies by the Gansu Academy of Agricultural Sciences (GAAS) have demonstrated the effectiveness of PRB farming, showing similar water productivity and yield gains to those found in PRB systems at the Shandong Academy of Agricultural Sciences (SAAS), the Indian Subcontinent, Australia and Central America. These, and other effects of soil management practices on the soils' hydraulic properties have been shown to alter the partitioning of the water balance, decreasing soil evaporation and increasing transpiration, infiltration (Figure 3) and deep percolation, leading to increased wheat yields and WUE in Shaanxi Province PRC (Zhang, 2006)

However key constraints to the practical implementation of these elements of CA in Hexi are; the lack of appropriate machinery, farmers are steeped in conventional tillage and flood or basin irrigation methods, competition for crop residues and whether or not an economic benefit exists from implementation of PRB in this region. The continuation of GAAS PRB research, and the extension of the PRB work in Shandong province into north-western China, will allow agronomic, water and residue management and mechanisation practices to be drawn together under the banner of CA and be tested under real world conditions. On-farm research will directly demonstrate to farmers the agronomic benefits to be gained from CA in this region, while the cost benefit analysis of the changed farming system will provide evidence of improved income, while using less irrigation water and other farm inputs.

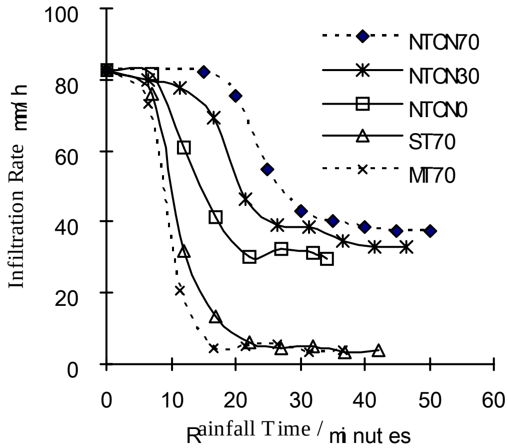

Figure 3. The change in infiltration rate with changes in level of compaction and cover. Where NTCN = No tillage no compaction plus cover (0, 30, or 70%), ST70 = compaction with small tractor (1.2t) + 70% cover, and MT70 = compaction with Medium tractor (3.6t) + 70% cover. (After Wang *et al.*, 2005)

EPILOGUE

Conservation tillage has been proven to combat drought and improve soil physical conditions in china. Increased water infiltration and reduction in water and wind erosion is achieved through no-tillage or minimum tillage, and stubble cover. Conservation tillage research started with the support from the Ministry of Agriculture (MOA) and an Australian Centre for International Agricultural Research (ACIAR) project in 1992. By the end of 1990's CT research was seen as very successful and therefore in 1999 MOA established the Conservation Tillage Research Centre to lead CT research in China. Following continued success, MOA established an ongoing CT demonstration project in northern China during 2002. As a result, by 2004 there was more than 4,000,000ha in 100 counties from 14 provinces under CT. The MOA initiative has spurred Northern provinces to commence their own trials and demonstrations of CT, further increasing the area under this advanced farming system. After 3 years of field demonstrations, CT adoption has been proven to increase farmer's net income by increasing yield and reducing production cost. CT also protects the environment by reducing water and wind erosion, and improving soil condition soil through no-till and stubble retention in the field. CT is viewed as a new agricultural revolution by many agencies in China. The challenge now is for Chinese agricultural to embrace the next step in the agricultural revolution, Conservation Agriculture.

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