Land management impacts on runoff and erosion, and linkages to environmental management systems

Summary
This project focused on GRDC Investment Objective 3: Protecting and enhancing the environment, and Program 3.1: Environmental management. The aim of this program was to develop environmental management systems (EMS) which enabled growers to better manage the environmental impacts of their grain production enterprises, and to assess the environmental impacts of dryland and irrigated grain production at the regional and national scales.

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Conclusions

Farming systems for grain production in central Queensland (QLD) need to quantify and address the environmental impacts of their farming enterprise if they are to remain sustainable and profitable. This project examined the effects of downslope controlled traffic farming (CTF) and contour farming on runoff, soil erosion and pollutant transport. Total runoff and soil erosion were highest under CTF, but CTF has been able to reduce erosion under large rainfall events. Zero tillage (ZT) has kept erosion rates low, regardless of row direction.

Average grain yield and gross margins for eight crops were higher under CTF. Atrazine\(^\#\) was the only pesticide detected in the runoff water. Exports of atrazine were highest three weeks after application, reduced to below guideline levels nine months after application, and not detected 18 months after application. Total nitrogen (N) followed a similar cycle to atrazine, but was always above guideline levels. Total phosphorus (P) was highly correlated to sediment concentration, regardless of farming system, but always above guideline levels. For these guidelines to be suitable for central QLD conditions, they need to take into account the climatic nature of sub-tropical and tropical regions, high clay content soils and soils with high P levels. Better management practices need to be implemented to reduce the off-farm impacts of applied nutrients and pesticides, particularly N and atrazine.

Recommendations

1. **Promote the need for downslope CTF** - this project provides new information on an initial constraint to the adoption of CTF - the erosion effects of downslope CTF layouts. Downslope CTF appears to control erosion better than contour farming under large runoff events, even though erosion rates from both systems have been low due to ZT and the maintenance of high stubble cover levels. The adoption of CTF has made the implementation of ZT much easier due to the precision of all operations (planting, spraying). CTF has also improved crop yields by 0.18t/ha, and increased gross margins by $19.90/ha. The results from this project are applicable to the shallow open downs soils which constitute more than 70% of the soils used for cropping in the Central Highlands. These results are further supported by a sister project on duplex soils near Bauhinia Downs (National Heritage Trust (NHT) project) where CTF has reduced soil erosion by 65% when compared to contour farming.

2. **Better management practices need to be implemented to reduce the off-farm impacts of applied nutrients and pesticides, particularly N and atrazine\(^\#\)** to meet guidelines and targets. Data from individual runoff events have shown that up to 14% of applied atrazine has been lost from the paddock from one runoff event three weeks after application. Similar losses for total N have also been measured. Possible management alternatives to reduce these losses could include:
   - Using early spring applications when rainfall amount and intensity are lower than the typical summer application period.
   - Establishing vegetative and riparian buffer zones (grasses, waterways, creek zones) to reduce runoff velocity, increase infiltration, and deposit eroded sediment.

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3. Need to conduct trials on a long term basis - although drought is and will continue to be a climatic constraint in central QLD, the time period covered by this project could not be considered to be representative of the long term seasonal conditions encountered in central QLD. The treatments have not experienced large episodic rainfall events (e.g. Capella 1994, Bauhinia Downs 1997, Comet 2002) to fully test the CTF system. Although this project is now funded under DNR14, no significant rain has fallen and no runoff produced 15 months into the three year term. Only long term trial sites can provide the opportunity to test any farming system across a wide range of seasons and provide the long term data required for modelling.

4. Need to model results - significant ‘value adding’ of the data can be made using computer simulation models. Simulation modelling would help develop a better understanding of the likely outcomes of these farming systems over a longer timeframe and a wider range of seasonal conditions. Results from this project would provide a valuable opportunity to validate existing models for central QLD conditions, leading to local validity and credibility.

5. Water quality guidelines need to be developed specifically for sub-tropical and tropical regions of Australia - in these regions, high intensity storms cause discharges of sediment at rates much higher than in temperate areas, where the data for the Australian and New Zealand Environment and Conservation Council (ANZECC) water quality guidelines are based. To be appropriate for central QLD conditions, guidelines need to be developed to take into account these seasonal conditions, high clay content soils and high P levels.

Outcomes

Expected Outcome (benefits)

Economic Outcomes

Ninety thousand ha of CTF has been adopted across central QLD. An average yield benefit of 0.18t/ha has been measured from eight crops (three sunflower, two wheat, three sorghum) grown during this project. This equates to an additional 16,200t of grain produced across central QLD.

An increase in gross margin of $19.90/ha has been measured from these crops. This is an extra $1.8 million across central QLD.

Environmental Outcomes

This project has shown that downslope CTF is able to control erosion under large rainfall events (although limited by the number of these events). This is also supported by a similar project on duplex soils where soil erosion has reduced from 13t/ha from contour farming to 4.5t/ha with CTF for 1999/2000.

Social Outcomes

Although there has been no measured evidence of social outcomes or change arising from this project (or other projects mentioned in this report), anecdotal evidence suggests that growers are able to ‘spend more time doing other things’ (repairs, maintenance, farm management) as less time is spent on the tractor. Those growers closely involved in this project are also becoming environmentally aware of the off-farm impacts of their farming practices. This has been a change in their social thinking of looking beyond the farm boundary. For example, landholders are more conscious of what may be in the runoff water (e.g. atrazine) and what they can do on-farm to reduce these off-farm impacts.

Achievements/Benefits

Overview of Project Achievements

The aims of this project were to contribute to sustainable farming systems through three processes:

1. Quantifying the benefits to on-farm soil quality.
2. Determining how improved land management can reduce erosion and pollutant transport.
3. Understanding the linkages between on-farm practices and off-farm environmental impacts.

Past constraints to dryland grain production in central QLD have been declining soil fertility, increasing soil compaction and losses from soil erosion. The effects of soil erosion are cumulative, resulting in major impacts on the environment. Farm layouts are dominated by erosion control structures which produce paddock inefficiencies of 10%-25% on all field operations, restrict the adoption of improved practices such as ZT, and increase soil compaction. Current production is clearly...
constrained by these limitations. The high erosion rates lead to major impacts on stream water quality, and are a major limitation to community support for the industry.

CTF can address some of the resource management aspects of erosion and compaction control, on-farm efficiency and support improved and innovative practices. Previous research and grower experiences have shown that CTF can increase grain yields, water use efficiency (WUE) and profitability. Major constraints to the adoption of CTF have been concerns about the erosion effects of downslope layouts.

To address these concerns, two treatments (downslope CTF and contour farming) were instrumented to measure rainfall runoff, soil erosion and pollutant movement within the Central Queensland Sustainable Farming Systems project (CQSFSP) (DAQ382). The site was further split for crop rotations (wheat and sunflower and continuous sorghum).

Rainfall

Rainfall for 1999/2000 and 2000/2001 was average (578mm and 598mm, respectively), while 2001/2002 was below average (390mm). Within these average rainfall years, there were extended periods of very dry conditions (e.g. July-December 1999 - 97mm, 2001 calendar year - 301mm).

Runoff and erosion

Five runoff events were measured from the wheat and sunflower rotation and 10 events from continuous sorghum. For both cropping rotations, total runoff from CTF was higher than from contour farming (Attachment, Table 1) by 34% for wheat and sunflower and 30% for continuous sorghum (Attachment, Figure 1). This may be due to the lack of downslope roughness in the CTF, compared to the contour farming which has the ability to maintain some runoff storage in the plant furrows across the slope.

Similar to runoff, total soil erosion was marginally higher under CTF than contour farming, but soil erosion rates were relatively low (less than 1t/ha/yr), regardless of farming direction (a function of the high cover levels maintained using ZT) (Attachment, Figure 2). In contrast, the downslope CTF layouts reduced soil erosion when runoff rates were high (greater than 20mm/hr). For example, on 19/11/2000 (75mm rain, maximum intensity 70mm/hr), runoff from CTF was higher than contour farming, but soil erosion was less (0.8t/ha, compared to 1.2t/ha). This indicates that CTF has the potential to control erosion under large rainfall events by minimising the formation of rills which are evident in the contour farming treatment.

Measurements of rill dimensions after the 19/11/2000 runoff event showed that the volume of rills in the CTF treatment (3.4m$^3$/ha, deposition 1.25m$^3$/ha) was lower than the contour farming treatment (7.2m$^3$/ha, deposition 0.33m$^3$/ha). These data show that under these large events, there is a high risk of loss of capacity of contour bank channels and mass bank failure in contour farming due to the higher deposition (generally deposited in areas at the end of the large rills) within the contour channel.

Opportunity cropping

Although treatment differences were measured from each cropping rotation, the biggest difference was between cropping rotations. Runoff from the wheat and sunflower rotation (opportunity cropping) was 4.4%-6.6% of rainfall, whereas runoff from the continuous sorghum rotation (monoculture) was 8.2%-11.7%. The majority of runoff (80%) from the continuous sorghum occurred during October-December 2000 when the soil profile was wet, but was not planted until January 2001. An attempt to plant spring sorghum in September 2000 was made, but was unsuccessful due to the wet harvest of the previous sorghum crop (header did not fit the CTF system). Header wheel tracks compacted 22% of the crop area, and 30% of the planted rows were going to be into compacted header wheel tracks.

Water quality

Samples were collected for the analysis of total P, total N and a range of pesticides from the continuous sorghum crop rotation only (due to lack of wet weather access to the wheat and sunflower rotation). Total P was highly correlated to sediment concentration, regardless of farming system. This indicates that P was probably derived from natural erosion processes. Figure 3 (Attachment) shows this strong relationship for the 32 samples collected ($R^2 = 0.75$). All samples greatly exceed the ANZECC guideline trigger level of 0.034mg/L for the protection of aquatic ecosystems at low flow. In tropical regions of Australia, high intensity storms on catchments cause discharges of sediment at rates much higher than in temperate areas where the data for the guideline levels are based. This may account for P levels being higher than the
guideline levels. To be appropriate for central QLD conditions, the guidelines need to take into account these naturally high background levels of P, and data need to be collected from undisturbed systems.

Total N increased after the application of fertiliser, indicating that applied N was being exported from the paddock, either in runoff or attached to the soil particles. Maximum concentrations of 6mg/L were measured within three weeks of application. The lowest concentrations (1-2mg/L) were measured at the end of the fallow, and prior to the next application (guideline level is 0.34mg/L).

Atrazine*, the only pesticide found, was detected in runoff water above the ANZECC water quality guideline of 0.5ug/L for approx. nine months after application, and by 18 months after application, it was not detected. Concentrations were detected up to 660ug/L three weeks after application, but these high concentrations rapidly decreased before and within the local water course, but were still above water quality guidelines. Figure 4 (Attachment) shows the typical annual fluctuation in atrazine concentrations throughout the cropping season.

Better management practices need to be developed to minimise the losses and off-farm impacts of applied nutrients and pesticides. These practices need to be designed to reduce the availability of the product for loss, reduce the impact of the first runoff event, and provide a mechanism for deposition of the applied product before it leaves the property. Possible practices to minimise these losses in runoff and erosion include using paddock conservation practices (e.g. ZT) to reduce sediment loads, using early spring applications when rainfall intensity is lower than the typical summer application period, using non-atrazine products (provided the environmental issues have been researched), manipulating plant density for weed control, and the establishment of effective vegetative and riparian zone buffers.

Grain yield

On average, CTF increased grain production by 0.18t/ha (0.31t/ha for wheat, 0.12t/ha for sunflowers, and 0.13t/ha for sorghum), compared to contour farming (data from project DAQ382). This represents an increased gross margin of $19.90/ha ($25/ha for wheat, $28/ha for sunflowers, and $7/ha for sorghum). Table 2 (Attachment) shows the yield and gross margin of each crop grown.

Adoption of CTF

An estimated 90,000ha of CTF has been implemented across central QLD, and 500,000ha nationally (report from NHT project 972255). Growers undertaking CTF have been able to overcome the physical barriers to adoption by modifying equipment to the correct machinery and row width combinations to suit all farming options, negotiate broad based work over contour banks, and identify wheel tracks. Social impediments to change continue to limit the adoption. A change in mind set of the grower is required before CTF is adopted (e.g. working within contour banks is changed to working over contour banks).

Other research

Other R&D Opportunities

This project and linkages to other projects (e.g. DNR14, DAQ382, NHT projects) have concentrated on cropping on the open downs soils of the Fitzroy River Basin. There is the opportunity to expand this focus into other key regional areas (landscapes) throughout the grain growing region. Focus catchments in these key landscapes will provide essential data sets on export loads of sediment, nutrients and pesticides for target setting and modelling, ecosystem services and production.

There is a growing need for continued research into specific CTF applications. Agriculture is moving towards more efficient, technological advances, such as GPS guidance systems (opportunity for alternative whole farm layouts e.g. curved rows and strip cropping), yield mapping and detailed soil nutrient testing. The CTF system provides a vehicle which many growers have used to move their agricultural enterprise forward.

An opportunity exists to measure and model the movement of sediment from cropping paddocks (source) through the upland catchment to major rivers, and ultimately the reef. Sediment tracking is a potential source for collecting these data. Stream flow and water quality resulting from a catastrophic rainfall event in the Comet River catchment was able to be tracked through 600km of river system, providing valuable information required for modelling and target setting.
Explore modelling opportunities of CTF systems where risk probabilities are applied to contour bank designs. What are the conditions when the system will most likely fail? Various slopes, contour bank spacings, wheel track capacities and cover levels can be used.

Additional information

The following articles were written to address the project outputs. These articles also form part of the broader 'Neighbourhood Catchments' project:

- Sustainable Farming Systems Project, Tri-project meeting, DPI Rockhampton, 22-24 August 2000, pages 61-65 - Runoff and soil loss from Controlled Traffic Farming (CTF) at two Central Queensland (CQ) Sustainable Farming Systems sites.
- Geospatial Information in Agriculture Conference, Sydney - Neighbourhood Catchments: Using geographic information system (GIS) to achieve ownership and change in catchment management.
- Australasian Pacific Extension Network Conference, Toowoomba - The Neighbourhood Catchment approach to achieving regional change.
- Aquatic Environments Conference, Townsville, November 2001, submitted but not yet printed - Neighbourhood Catchments: Integrating land management research, geographic information systems and extension to achieve change in the aquatic environment.
- Australian Grain - Controlled Traffic Farming (CTF) - the need to fit the header into the system.
- The 2001 Australian grains field research manual, pages 67-70 - Runoff and soil loss from controlled traffic and contour farming.
- The 2002 Australian grains field research manual, submitted but not yet published.

Attachment

Supplementary data - Table and Figures.