Australian Government
Cotton Research and Development Corporation

COTTON AUSTRALIA

Australian Government
Department of Agriculture, Fisheries and Forestry

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EMS Pathways to Sustainable Agriculture for the Cotton Industry

A discussion on the role of monitoring in evaluating industry NRM performance

June 2008

Natural Solutions are independent consultants assisting in project

AS / NZS ISO 9001:2000					
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1.0 OVERVIEW

Assessing changes in resource condition is seen as an essential element for evaluating the impact of public and private investment in natural resource management (NRM) outcomes. Some observers suggest there is little to show in terms of improved natural resource condition for investment over the last 20+ years. In the language of NAPSWQ and NHT, the link between management action targets (MATs) with timeframes of 1-5 years and resource condition targets (RCTs) with 10-20 year timeframes has apparently not been made with sufficient rigor to convince policy makers of the value of NRM investment.

Agricultural industries are also keen to demonstrate their environmental credentials given they often feel targeted as the perpetrator of environmental harm in some debates despite significant individual and collective investment in developing and applying more sustainable practices.

This paper offers some observations and suggestions to progress the discussion on how to better assess changes in natural resource conditions that are within the capability of industry and regional NRM groups (the later are generally referred to as NRM Regional Bodies or Catchment Management Authorities).

While we suggest that monitoring of resource condition *per sec* will not be useful within the time frames and resources available to most groups, there are a number of approaches that can be adopted that will help inform and allow for reporting on improved management and subsequent natural resource condition outcomes. We suggest there is a role for enlightened monitoring to be carried out to establish baseline data at a range of scales (from sub catchments to basin) although this is probably the responsibility of government authorities with significant resources and tenure beyond that available to smaller groups.

This discussion is informed from experience gained as research scientists studying catchment behaviour in the northern Australia. We have been involved in development and application of environmental performance indicators in crop and pasture production systems

Experience from the "EMS Pathways to sustainable agriculture for the cotton industry" project crystallised much of this discussion when we had to take the paper based theory out to the real world. The environment we operate in is characterised by extreme variability in weather and associated hydrology.

We outline why monitoring resource conditions to assess impacts of investment will most likely not be productive. We present some arguments as to why management actions and attitudes can and should be used to measure progress. While water quality was chosen as the focus of this discussion (our area of expertise or comfort), there is no reason why the logic presented will not apply to other elements of ecosystem function such as biodiversity or soil health.

2.0 SUMMARY

1. Monitoring in a catchment setting will observe: variability within and between hydrologic events (hydraulic and hydrologic drivers); differences associated with scale; natural catchment conditions (weather) and management. It is extremely difficult to attribute changes associated with management in intrinsically variable environments.
2. Therefore, monitoring of most resource condition indicators is unlikely to yield data that is useful in demonstrating change associated with investments.
3. Regional bodies and catchment management authorities are unlikely to have infrastructure (data management and analysis) or security of tenure (commitment to decades of sampling) to support long term monitoring that would be amenable to detailed analysis.
4. Monitoring by the community and its service organisations will only be sustainable (i.e. applied in the long term) if it is useful in directly guiding action – there has to be a continuous and direct link between action and observation.
5. Management actions can be robustly linked to resource conditions. The challenge is to develop these relationships to a point where they are accepted by all stakeholders.
6. Models help structure data and expertise, and allow us to extrapolate our understanding to conditions beyond the limited conditions experienced in research studies. They are an essential tool in NRM but should not be taken literally.
7. Since people manage the system, their knowledge, intentions and attitudes are central to management. Therefore, knowledge, intentions, attitudes and behaviour should be monitored as part of any evaluation process.
8. A range of approaches is required to demonstrate value of NRM investment including; random, stratified, and *a posteriori* surveys, reference benchmarks, sentinel sites, remote sensing and case studies.
9. Monitoring of resource conditions remain essential as "points of truth" and as reality checks when calibrating models. There is a case for long term monitoring (decades) within a secure and committed organisational setting.

3.0 INTRODUCTION

After considerable investment in NRM, some observers suggest that there is little to show in terms of improved natural resource condition. In the language of NAPSWQ and NHT, the link between management action targets (MATs) with timeframes of 1-5 years and resource condition targets (RCTs) with 10-20 year timeframes has apparently not been made with sufficient rigor to convince all stakeholders of the value of public investment in NRM. It seems a reasonable expectation that significant public investment should be able to demonstrate positive changes.

This discussion paper outlines why it is difficult or unrealistic to expect the connection between MATs and RCTs to be made. We also present some arguments as to why knowledge, attitudes and management actions should be used to measure progress.

3.1 WHY MONITOR?

Agricultural and NRM organisations have been exploring the use of environmental performance indicators for the past decade. Some key motivations for the search for indicators include:

- Accountability for science, extension and land use practice;
- Assessing condition and responsiveness of various elements of the landscape to target investment;
- Supporting demand for improved farm management and investment decisions;
- Benchmarking management actions and resource conditions;
- Measuring individual and community knowledge (e.g. changes in knowledge, attitudes, skills, aspirations, practice);
- Adherence to national and global policies (e.g. Kyoto greenhouse protocols);
- Striving for excellence and NRM stewardship.

3.2 IF WE MONITOR RESOURCE CONDITIONS, WHAT ARE WE SEEING?

It helps to be clear about what to expect if we monitor. In this discussion, hydrology and water quality data from catchment studies in southern Queensland are used to demonstrate possible outcomes from a monitoring program. This data was collected as part of a research program over 20 years; a situation of relative luxury in terms of data richness and completeness.

Assuming that measurements are accurate, an observation or measurement will produce variable results due to:

- Sampling error within an event or area;
- Natural variation associated with weather;
- Scale or location in the catchment;
- Change associated with land use and management (the purpose main of monitoring in this papers context).

Further discussion of these errors and impacts follows.

1. Sampling error – the sample collected is often too small to be representative of the larger unit of interest, especially if spatial or temporal variation is naturally high.

Most physical variables used to describe the environment exhibit high spatially or temporally variability. For example, a soil sample of 0.1 kg, even if replicated several times may not represent even one hectare. **Figure 1** shows the variation in sediment concentration within a runoff event over 25 hours. A sample collected randomly during this event could provide a sediment concentration value of between 4 and 17 kg m^{-3}. Samples collected at the beginning of the event would grossly overestimate total sediment load while samples taken later in the event would underestimate loads. In this case, differences due to management need to be much greater than these differences to demonstrate changes associated with changed management.

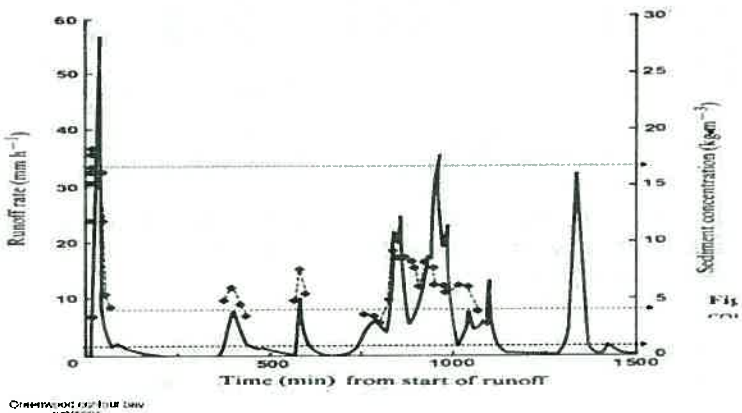

Figure 1 ***Hydrograph and Sediment Concentration During a 25 Hour Runoff Event from a 1 ha Contour Bay Catchment. Note variation in Sediment Concentration Over Time. (Freebairn and Wockner, 1986b)***

2. Natural variation associated with weather – a climate which has large variations in rainfall patterns and intensity results in equally variable and unpredictable runoff, erosion and water quality.

Some degrading processes are highly episodic, being driven by extremes in weather (wet, dry, hot, cold). To demonstrate this variability, average erosion rates measured for consecutive 3 year periods varied from 14-78 t/ha/year for a small catchment study on the Darling Downs (**Figure 2**). Over a 14 year period 81 rainfall events resulted in runoff with 556 t ha^{-1} of soil movement. More than 70% of this erosion resulted from just six rainfall events (Wockner and Freebairn, 1990). Even when management impacts are large, it is difficult to detect whether a change in erosion was due to management or chance unless a side by side comparison can be arranged, similar to research studies.

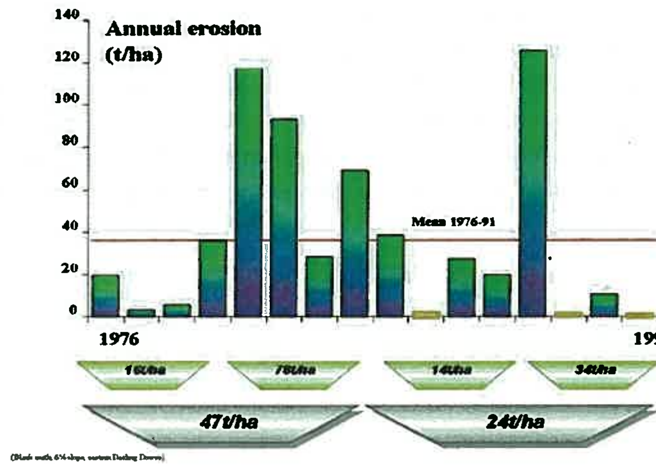

Figure 2 ***Annual Erosion from a Contour Bay with Winter Crop, Bare Summer Fallow, Showing Extreme Variability in Erosion Rates Even Though Management was Constant (Wockner and Freebairn, 1990).***

At the larger catchment scale, stream flows are equally variable (Figure 3). Many streams in northern Australia have very low flows for greater than 70% of the time! This in itself makes sampling difficult, and interpretation of collected samples challenging. It is easy to imagine why a sampling regime based on fixed dates might miss the main hydrologic events, sampling a series of low flows for years or decades (Figure 3).

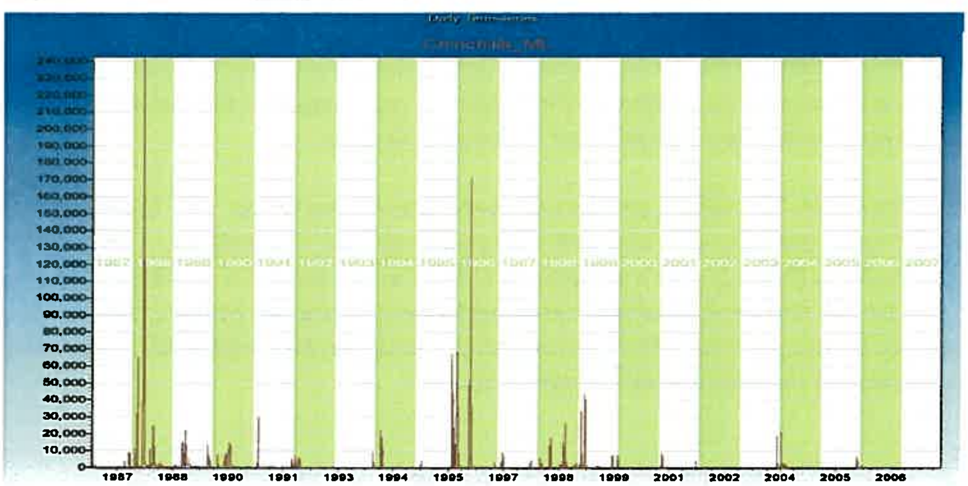

Figure 3 ***Daily streamflow for the Condamine River at Chinchilla weir (1987-2006).***

3. Scale and location – hydrology, erosion and sediment transport are strongly influenced by scale or catchment size.

As catchment area increases, the impact of management declines. Storage in the system, time lags and dilution result in attenuation of management impacts. Dilution refers to the managed area being a small proportion of the catchment. For example, changing 2% of a catchment to a new practice that reduces erosion by 50%, in an environment with a natural coefficient of variation in runoff and erosion of >70% means that any changes in water quality due to investment are unlikely to be seen at the catchment scale where this change might be in the order of 1% (0.5 * 0.02 =0.01).

Figure 4 shows a photo mosaic of catchments from 1 ha to 1 million ha. Small catchments (< 50 ha) responds to rainfall in < 1 hour, while large catchments take weeks to months for a flow event to pass. This variation in catchment response time make sampling difficult, either being too fast to capture samples or too prolonged to collect representative samples. In either case, samples need to be taken throughout an event to provide a reliable estimate of total load.

At the paddock scale, management impacts are generally clear while the sub catchment or catchment has a range of land uses, management practices, soil types, topography and even climates. Figure 5 shows the changes in observed phosphorus and nitrogen in runoff water for three sizes of catchment on the eastern Darling Downs. As expected, changes in scale through several orders of magnitude (factors of 10) result in changes dissolved nutrients of at least two orders of magnitude. Therefore any sampling regime needs to be designed to minimise impacts of scale unless this is the question being explored.

It would be naïve to expect that changes at a paddock or farm scale might be reflected even at the sub catchment scale unless very large parts of the catchment were subject to change.

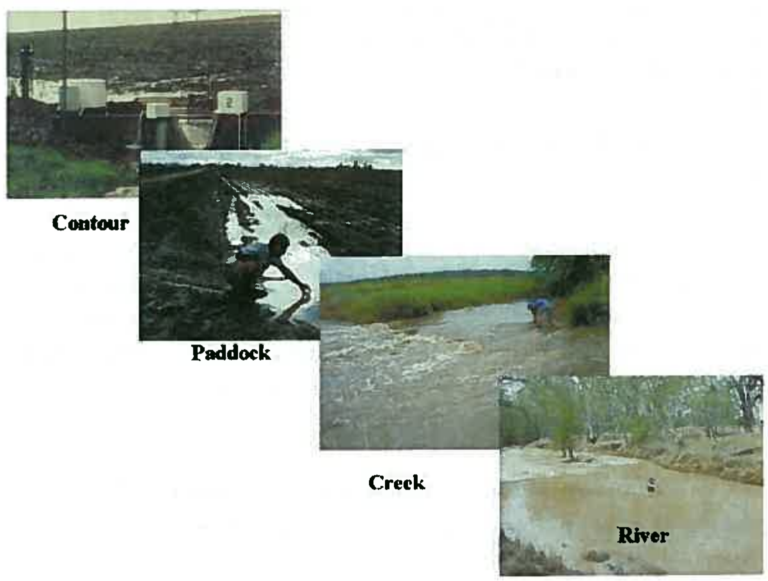

Figure 4 *From 1ha to 1 Million ha Catchments. THIS RANGE of Scales Poses Challenges for Monitoring and Interpretation*

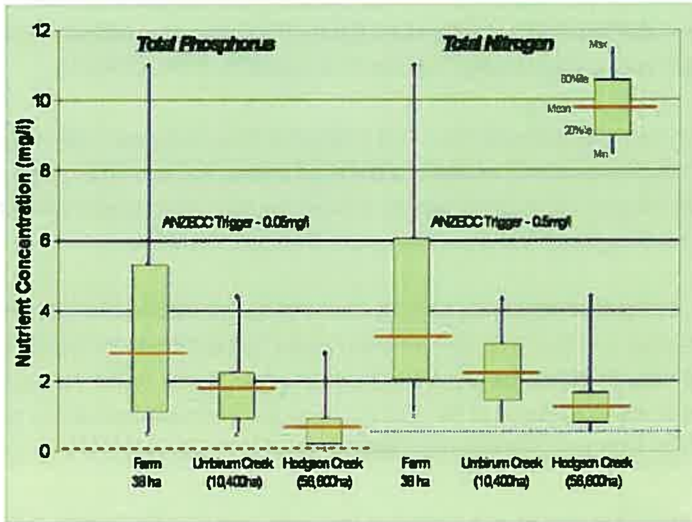

Figure 5 ***Box Whisker Plots of Total Phosphorus and Nitrogen in Runoff from a Set of Nested Catchments on the Eastern Darling Downs (Silburn et al., 2007). Concentration of Nutrients in Runoff Varies by an Order of Magnitude Across 38-56,000 ha, Reflecting Deposition and Dilution as Area Increases***

4. Change in land use and management – responses to management is the crux of what monitoring and evaluation is about.

Figure 6 shows a relationship between soil cover and sediment concentration derived from a set of 4ha catchments which were monitored intensively for >10 years. Even though there is a clear relationship between cover and sediment concentration, there is still significant variation attributed to different hydrologic conditions, and other physical factors such as roughness, storage and soil moisture. Similar relationships have been found for many other catchment and rainfall simulator studies, and this relationship is similar to that used in the Universal Soil Loss Equation (Wischmeier and Smith, 1978), a model used extensively in the USA for allocation of NRM resources.

Practice change needs to be recorded at the scale of change, whether this be paddock or farm scale, and results aggregated up to any higher level. Changes in an environmental value (e.g. water quality) can be deduced by simple models or relationships (Rattray *et al.*, 2005, see **Appendix 1**)

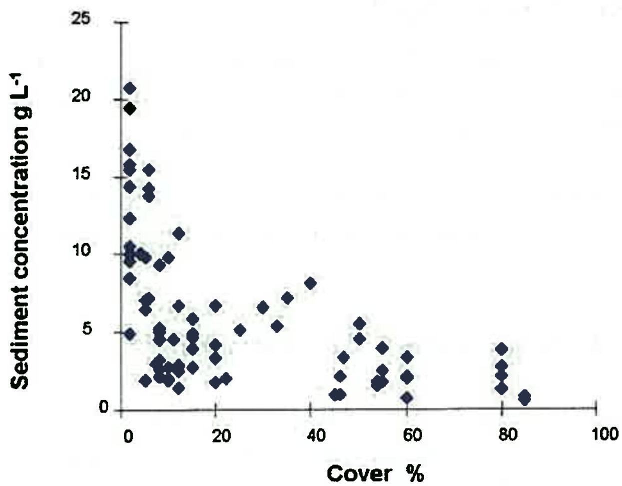

Figure 6 ***Relationship Between Soil Cover and Sediment Concentration Leaving Contour Bay Catchments near Wallumbilla (1983 -2000) (Freebairn et al., 2009).***

4.0 DEALING WITH VARIABILITY

While resource conditions may be intrinsically variable, making attribution of changes associated with investment difficult, the following case study provides an example of where change in management at a range of scales can be used to infer with confidence that change has indeed occurred.

We use soil erosion and water quality as an example of a resource condition that can be monitored in a number of ways. Erosion has been used as it is an area where we have technical expertise, and also because it is one of the more challenging NRM issues we deal with.

4.1 A CASE STUDY LINKING MANAGEMENT TO A RESOURCE CONDITION.

We know from research studies, that there are good relationships between on-ground conditions (soil cover), erosion and water quality. Soil cover can be measured reliably using a range of approaches, but soil cover also varies with season, crop, and management. Changes due to management (tillage or grazing) can be large, and are of similar magnitude to those that occur through time in any system. Therefore monitoring of cover in itself can be difficult. The issue of temporal and spatial variability can be dealt with by asking land managers to estimate their average cover conditions during high risk periods. We can assume they can provide an averaged estimate that reflects their intents and likely on ground outcomes. This process seems rather subjective, but reliable estimates can be achieved using trained surveyors. This process is similar to that used in polling people's attitudes in a wide range of topics including political intentions, which have proven reliable within known errors.

One step removed from land manager surveys is to relate cropping, tillage or grazing practice to cover using established relationships such as presented in **Table 1**. For example, cover in a critical storm period under a winter crop - no till fallow system would be >80%, and <15% where the soil is tilled aggressively. Thus we can simply ask what approaches to tillage or grazing are adopted.

Estimate of cover can be derived for an industry or region by recording tillage implement sales (**Figure 7**). While this might seem to be a long set of connections (tillage sales – cover – erosion), we are close to what the land manager is thinking and doing. This linkage can be converted to a quantitative change in erosion or water quality through the application of simple but well supported relationships from research studies in the literature such as shown in **Figure 8**.

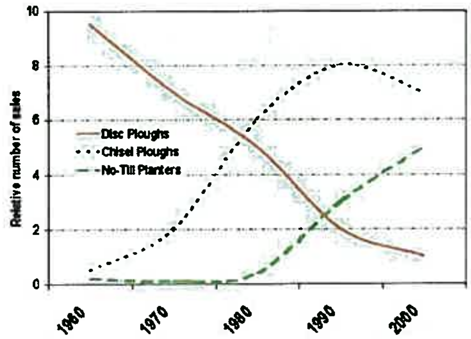

Figure 7 *Qualitative trends in machinery sales in southern Queensland, 1960-2000. Data from a survey of machinery manufacturers' farmers and scientists involved in conservation tillage research and extension in southern Queensland (Freebairn and King, 2003).*

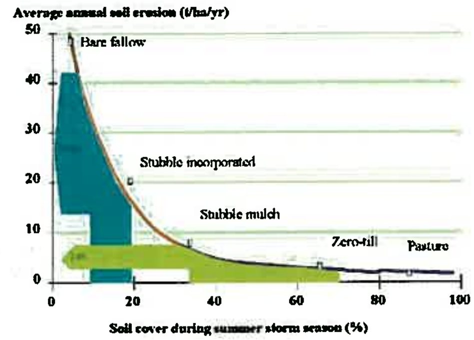

Figure 8 *Relative erosion rates for the 1970's and 2000 based on changes in soil cover associated with different tillage practices. Erosion rates have declined from 25 t/ha/yr to 5 t/ha/yr due to adoption of improved management.*

A schematic of how these data sources are linked is shown in Figure 9. The rationale is; erosion rates and water quality are closely linked to soil cover. Tillage practices directly influence soil cover. Therefore, tillage sales are an indirect but robust measure of practice, soil cover, and resultant erosion.

TABLE 1 EXPECTED SOIL COVER DURING THE CRITICAL SUMMER PERIOD (OCTOBER –MARCH) FOR A RANGE OF CROP AND TILLAGE MANAGEMENT OPTIONS (FREEBAIRN AND KING, 2003).

PREDOMINANT CROP-TILLAGE MANAGEMENT	TYPICAL SOIL COVER (%)
Grazed oats	<5
Winter crop – summer fallow, stubble burnt or incorporated (disc plow)	<5-15
Wheat – fallow, stubble retained (sweep plow)	30-50
Wheat – fallow, no- till (herbicide weed control)	>60
Summer crop -Sorghum, stubble retained	>60
Summer crop – Sunflower, stubble retained	30-50
Pasture, heavily grazed	<50
Pasture, well managed	>80

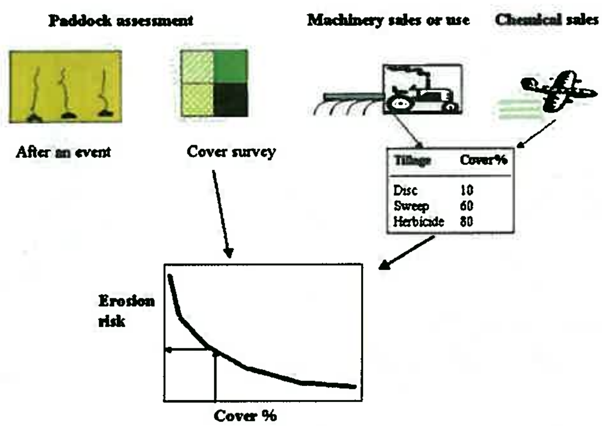

Figure 9 ***Schema for Linking Field Observation, Machinery and Herbicide Sales to Erosion Risk Assessment. Paddock Assessment Refers to Surveying Erosion After Events (Shown as Rills and Silt Deposits in Contour Channels), and Estimating Soil Cover Visually, with Cover Standards***

An advantage of using a range of indicators, all focusing on erosion and water quality in this case, is that there are good linkages between practice and environmental risk, and there are a number of ways of collecting and using data. More importantly, land managers can easily compare current and proposed practices at a level which is meaningful to them (i.e. there is no need for any complex transformations or models to provide credible explanations). Will policy makers be equally accommodating and pragmatic?

4.2 Some Reflections Estimating Cover with Growers Using a Ranking Schema.

As part of a project "EMS Pathways to Sustainable Agriculture for the Cotton Industry" a workbook for Assessing Environmental Performance Indicators was developed with the view that soil cover would be a useful indicator of soil stability and water quality. Issues that evolved when testing with growers and industry support staff were:

- Cover is not required in irrigated systems with low slopes where cover can impede water flow;
- While erosion from storm rain may not be the main soil issue in irrigated systems, management of water flows to protect infrastructure and reduce sediment movement during irrigation becomes more important;
- It was difficult to estimate an average cover for any particular situation because of season, rotation and paddock variability. **A simple estimate of soil cover turned out not to be so simple after all!**

The Cotton BMP process adopted "erosion risk is identified and managed" and "adoption of erosion and water management plan" as indicators of best practice. This approach allowed farmers to rate their application of these indicators (see below).

S1: EROSION RISK IS IDENTIFIEID AND MANAGED

Erosion and soil cover is typically most important for dryland crops on sloping areas. Erosion can occur at any time of year, but summer is a period of higher risk.

S2 below may be more relevant for irrigated crops.

Rank 1	Rank 2	Rank 3	Rank 4	Your Ranking
Areas of erosion risk have been identified.	Areas of erosion risk identified.	Areas of significant erosion risk (high slopes and areas near water flow lines).	Erosion risks on the property have not been assessed or addressed.	
Regular monitoring for erosion problems.	Structural and agronomic measures in place to minimise erosion in susceptible area.	Some conservation structures agronomic measure adopted to minimise erosion.		
Structural and agronomic measures in place to minimise erosion in susceptible areas.	Action is taken to repair and prevent individual erosion events from re-occurring.			
Filter strips and sediment traps in place and maintained				
Erosion and water management plan' in place				
Soil cover in high risk areas during summer is				
>40%	20-40%	10-20%	<10%	
				

S2: ADOPTION OF EROSION AND WATER MANAGEMENT PLAN[2]

S2 focuses on irrigated crops and dryland crops on floodplains.

Rank 1	Rank 2	Rank 3	Rank 4	Your Ranking
All tailwater is recirculated. Overland flow is slowed to promote infiltration.	All tail water is recirculated. Overland flow is slowed to promote infiltration.	All tail water is recirculated	Very little or no recirculation of tailwater	
In-field erosion is minimal, furrow lengths take into account soil type, slope and rainfall intensity.	Reasonable design of fields to minimise erosion, desilting of tail drains and canals required infrequently		Or Little attention paid to minimising erosion; high silt loads in irrigation canals, tail water drains and tail water return canals	
Fields are laser levelled where required to remove low spots.				
De-silting of tail drains and canals is only required occasionally.				

These groups of practices are less constrained than a simple estimate of cover and better accommodate a set of intentions and broad practices.

4.3 COMPLIMENTARY APPROACHES TO MONITORING AND EVALUATION

This paper has focused on using cover and tillage to estimate erosion and water quality to demonstrate a number of ways to assess changes in resource condition. We have indicated that this type of data can be collected in different ways. The following are suggestions on other approaches to collecting data that can be used to assess impact.

4.3.1 Surveys

Catchment managers, informed people or the general community can be surveyed to ask them about their practices, attitudes and aspirations. These surveys can be complete, random, stratified, *a pirori* or *a posteriori* qualitative or quantitative. Surveys can ask people about their practices, knowledge, attitudes, skills and aspirations (Bennett's hierarchy).

Inputs can be monitored in some cases as a measure of adoption of a particular technology. For example, Lucerne seed sales will be correlated with establishment of perennial pastures that may have NRM outcomes such as reduced deep drainage and salinity risk. Fertilizer sales and export of nutrients at a regional scale can be used to assess nutrient balance at a range of scales from farm to region or nation.

It is suggested that if a survey is used to assess progress in NRM that a stratified random design be used that has a balance of questions considering practice and attitude. Surveys should be delivered by a trained person (in person), rather than mail out or web based.

4.3.2 Remote Sensing

With developments in technology, some parameters may be observed remotely. For example, extent of natural vegetation can be detected by satellite imagery with some on-ground testing. Soil cover may similarly be measured. A downside of remote sensing is the poor connection between the land manager and the variable being measured, and may create a sense of 'spy in the sky' which is unlikely to be conducive to collaborative action.

4.3.3 Sentinel or Reference Sites

Sites can be established to represent a larger part of the landscape, where resource conditions are monitored to a) detect changes under a range of pressures (similar to the "canary in the coal mine") or b) act as reference sites for comparison with areas managed differently. Such sites may require significant investment initially but provide benchmarks for a wide range of environmental changes, and as demonstration and educational settings.

4.3.4 Case Studies

Case studies refer to an analysis and documentation of real life examples of a range of experiences. They can be created quickly, cover a wide range of situations but suffer from being qualitative in terms of interpretation. A good case study is a mix of land manager practice and science to explain some of the responses and has a sense of story telling, an important communication mode especially in NRM which requires a blend of social and technical content. A good example of case studies is available on http://www.landwaterwool.gov.au/products/pk050950. The Land Water and Wool program developed 10 case studies on woolgrowers managing rivers, streams and creeks as part of their overall farming system. The case studies were designed for use at field days and workshops.

4.3.5 Long Term Monitoring

Monitoring of resource conditions (inputs, outputs and system status) is an essential part of understanding relationships between management and environmental and biophysical performance, especially in a variable climate. These "points of truth" describe part of the real world and act as reality checks for models. Currently there are very few long term sites that are managed with a view of being retained infinitum. Therefore we are dependent on a small set of relatively detailed process studies or research sites that typically have < 10 year tenures.

There is a case for long term monitoring. Currently it appears to be a responsibility that no organisation is keen to take on because of the perception that such sites have high costs and diminishing social returns with time. This leads to an increasing reliance on models, and is an issue that deserves more discussion.

4.3.6 Adaptive Management and Monitoring

Monitoring integrated with management is often termed adaptive management. Management is adaptive when management actions are measured and evaluated before and after they occur and the resulting information is then used to refine the next round of management questions. Consequently, adaptive management can be thought of as a hybrid between pure research and seat-of-the-pants management. Within this system, monitoring is incorporated to collect data that will gauge the relative success of the management actions. The key is to conduct monitoring specifically to adapt management, rather than monitoring simply to build an information database.

"The long-term success of ecologically-sensitive development and management is dependent on ... our ability to learn and adapt from our past successes and failures, and our willingness to try novel approaches to ... management. Such adaptive management is an ongoing process that is refined over time with accumulated knowledge and continual learning ..."

The goal of adaptive management is not learning for learning's sake. The goal of adaptive management is exactly the same as that of the management action itself (i.e. changing habitat or wildlife populations in some way). The subtlety is that adaptive management actively incorporates feedback and learning into the process so that you learn from your management actions and can better and more quickly adjust those actions over time. Under adaptive management, monitoring is conducted to improve your management, not to simply gather information about the status of your animal populations.

"When you have got very little data one of the most interesting things about ecology and applied ecology is the idea that we can manage the system to learn things faster. So if we don't understand what is going on with "soil health", maybe we can manage the system to learn some of those parameters faster through changing grazing or cropping practices experimentally at a large spatial scale. This will incur a management cost in the short term but may lead to better predictive models in the long term which means better management. Ultimately what is the price we are willing to pay to have more understanding of a system and better predictive models?. We call that active adaptive management, and probably the only prospect in this country of our getting better natural resource management understanding is that we deliberately manipulate the system but not just to get profits and gains. We manipulate these large-scale systems to maximise the rate of information gain. "(J Garden pers. comm. 2008)

4.3.7 Research

When the relationship between management and NRM outcomes is poorly understood, there is a case for carrying out investigations to better define biophysical processes. The relationships proposed to support monitoring of water quality described in this paper have come from detailed and in some cases long term research studies. Technology development may be required to better manage systems where current solutions are either impractical or uneconomic. No amount of monitoring will help better manage a system if the basic processes are not well understood or the means to manage them is not available.

4.3.8 Targeting Key Assets

A complimentary approach to NRM investment is the identification of key assets that require protecting, and focusing on management options that provide the best return on investment for these assets Pannell (2008) describes an approach that requires identification of public and private assets, whether they are local or dispersed, and then applies a decision tree framework toward suggested interventions.

4.3.9 Comparison of Assessment Methods

The following table is a summary of advantages and disadvantages of a range of approaches to assessing changes in water quality, either directly or indirectly.

TABLE 2 COMPARISON OF VARIOUS METHODS FOR MONITORING WATER QUALITY AND EROSION

METHOD	ADVANTAGES	DISADVANTAGES
Automated flow weighted sampling	Full picture of flow regime	Expensive, requires long term technical support
Regular interval sampling of water quality with flow measurement	Structured, most likely to be maintained as regular procedure, samples all flows eventually	Miss main action in an ephemeral environment, expensive
Event based sampling of water quality, with flow measurement	Semi-structured, sample when most flow occurs, gives best picture of within event variability and total loads, adds value to gauging site	Difficult to resource
Event based sampling of water quality, no flow measurement	Semi-structured, sample when most flow occurs, gives picture of within event variability	Difficult to resource, can't estimate loads
Random sampling of water quality, no flow measurement	Simple, unstructured, gives a quick view of what is out there	Use only for awareness, no quantification or ability to extrapolate
Instrumented small catchments and plots (research)	Full control and description of catchment conditions, know what you are measuring	Expensive, time consuming
Adaptive management and monitoring	Involves wide range of skills, responds to emerging needs, well linked to community, can be low cost, part of ongoing learning	Requires skilled facilitation
Cover –local assessment	Simple, gives a quick view of what is out there, valuable if time series, engages land managers	Use mainly for awareness
Cover –remote assessment	Fast, wide spatial coverage, captures long term changes if images available, objective	High technology, soil colour, moisture influences result, needs calibration, does not engage land manager
Tillage practice –current	Rigor determined by resources available, can be beginning of time series, local engagement	Snapshot, take time for record to be meaningful, subject to seasonal conditions, indirect measure
Tillage practice sales -historic	Rapid, local to regional perspective, captures long term changes	Semi-quantitative, relies on memory, indirect measure

Assumptions:

When samples are collected, the condition of the catchment is known and recorded i.e. ask where is the water coming from?

Even when flow is not measured, rainfall records are needed to put samples in context, or else do not bother.

5.0 SOME QUESTIONS TO CONSIDER

5.1 ARE WE LIKELY TO BE ABLE TO MEASURE RESOURCE CONDITIONS AND DETECT CHANGES DUE TO MANAGEMENT?

A synthetic data set is used to determine what might happen if we had long term data on erosion from two different management practices on identical paddocks or catchments **Figure 11** shows a time series with 1o year running means calculated for the two land uses. The new management practice reduced erosion by 20%, a reasonable expectation over any project life or even decade.

The question we asked of this data was - what are the chances of showing this change if erosion was monitored?

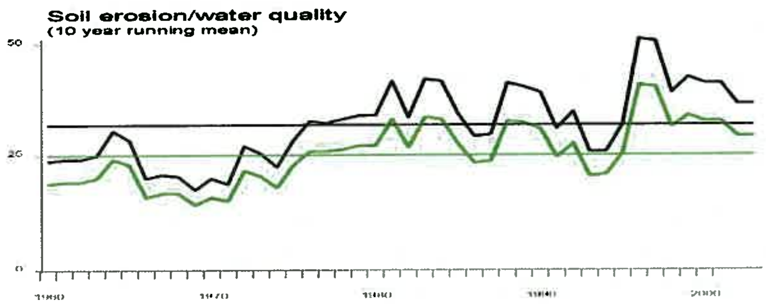

Figure 10 ***Time Series Showing Two 10 Year Running Means of Erosion Where the Green Line Represents a 20% Reduction in Erosion***

In summary, there would be a 23% chance of "observing" greater erosion using long term (1950-2003) as a benchmark, even though there was 20% decline. If we used last 30 years as benchmark, this increased to 40% because this period was wetter than the longer term mean.

It is unlikely that we would be able to support a monitoring program that has the rigor to maintain methodology, archive data and interpret the data in such natural variability. This analysis does question the validity of collecting samples of water for analysis unless these observations can be put into context. Such analysis is not trivial.

An example closer to home might be more tangible. Consider what conclusions we might make if we had been sampling water quality over the last 10 years. The last five years would most likely show that erosion has declined dramatically, as has runoff! The recent drought would bias the results considerably.

5.2 WHAT IS THE ROLE OF MODELS IN ASSESSING CHANGE?

Models are regularly used in NRM research and development yet there are conflicting views about their validity as tools to support planning and evaluation. Much of this mistrust comes from their lack of transparency and the fact that models are used by a small group of specialists. What you don't understand you don't trust.

Models can be simple or complex, the simpler the better (see comments below). Models help structure data and extrapolate our understanding beyond limited conditions we have measured. **Figure 6** is an example of a model showing the relationship between soil cover and erosion while Figure 8 is an application of that model to estimate changes in erosion over 30 years.

Models allow us to analyse some aspects of production and natural resource management that cannot be done efficiently with traditional experiments. Models rely on sound experimentation to provide a basic understanding of processes. By combining knowledge gained from many experiments and using long term weather records, estimates can be made of what is likely to happen in other environments, soil types and inputs. Models help us think through what are the most important processes in a system but they will always be incomplete because we don't know everything even from detailed experiments. Models do not invent knowledge; they are good integrators and data stretchers.

To add some balance, models are never correct but they are often useful. They should not be taken literally.

"You can use all the quantitative data you can get, but you still have to distrust it and use your own intelligence and judgment".
Alvin Toffler

Typically models can be applied with data from monitoring or surveys.

5.3 CAN THE ONE INDICATOR BE USED AT DIFFERENT LEVELS OF SCALE?

Most indicators can be aggregated at the regional level, BUT, there are few good reasons why an indicator should be aggregated up or across regions. As scale changes, the audience and of an indicator may also change. Any one indicator may have a different response shape depending on the land use system. For example, more herbicide use could be considered positive for erosion control, but negative for herbicide resistance and water quality.

5.4 CAN WE AGGREGATE CHANGES AT PADDOCK OR FARM SCALE UP TO A CATCHMENT?

There are few studies in the literature that go beyond small plot or catchment scale in terms of demonstrating water quality responses to land use or management, and such interpretations are typically left to simulation analysis. Models are only a representation of reality, but often are the only way we can put things together in a realistic time frame and cost. Rattray et al. (2006) proposed a simple basis for stretching such analyses to the sub catchment scale using a combination of water balance modelling, simple water quality models such as shown in **Figure 6**, GIS and local expertise to assess changes in water quality and sediment delivery at the catchment scale (**Figure 10** a and **b**). **Figure 10a** shows those parts of the catchment contributing the most sediment, and also where investment might be targeted to improve water quality. A brief description of RAPUP is presented in **Appendix 1**.

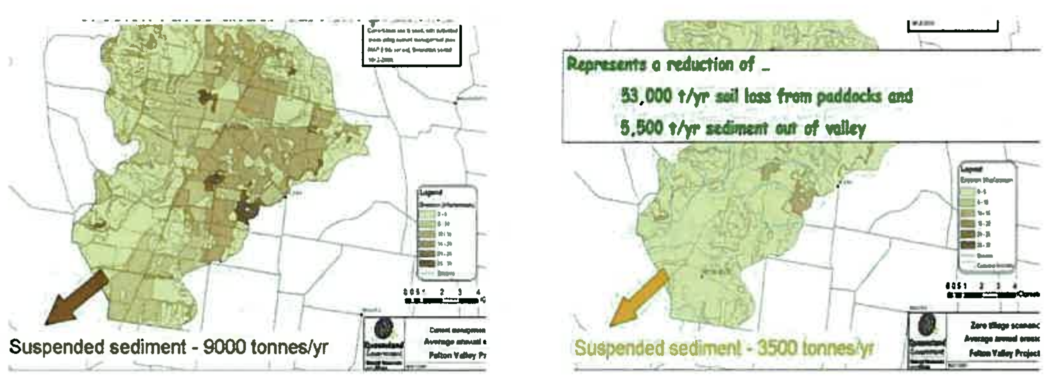

Figure 11 ***Maps of the Felton Valley catchment near Toowoomba Showing Erosion Rates and Sediment Delivery at the End of Valley for (a) Current Land Uses and (b) if Conservation Tillage was Adopted (Rattray et al., 2005).***

The challenge is to demonstrate changes in environmental performance that reflect management change due to investment and are not confounded by variation due to sampling error, natural variation due to weather or scale.

5.5 ARE MORE DETAILED MEASUREMENTS OR MODELS BETTER?

Complex solutions are not always the best solution, as complexity carries many overheads. Ward (2005) described the simplicity cycle (Figure 12) where in some cases adding complexity makes things less useful. There are many examples in industry where, as technology has matured, the process or equipment is simpler, more reliable and efficient. We need to be always asking the question: which piece of this complex system can I remove without affecting performance? Technology should be critically reviewed to explore whether further developments are leading to increased complexity and diminishing returns to functionality.

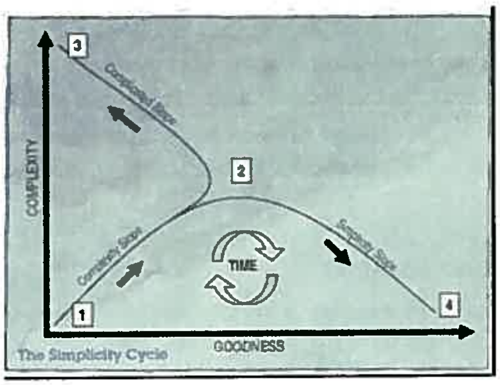

Figure 12 ***The Simplicity Cycle (Ward, 2005)***

5.6 IS IT WORTH MONITORING ANY RESOURCE CONDITION INDICATORS?

The points presented above support the proposition that MATs are measurable and can be linked to RCTs with reasonable confidence. RCTs should be monitored as reality checks but more importantly to inform and reference a range of models that can be used to translate MATs to RCTs. It needs to be remembered that many RCTs, especially those suggested by technical specialists require special skills and resources, and often do not have meaning to managers who manage the land and water resources.

Models allow us to put best bet information together, relating changed practices to improved environmental performance, and eventually to end of valley outcomes. When models are used for this purpose, they need points of truth, and special effort needs to applied to make these models more transparent and credible. The USLE is used routinely in the US to determine a wide range of government support measures, and as such has taken on the mantle of being the undisputed opinion on many soil erosion issues. This model was the product of approximately 10,000 plots years of data, and thus has a solid database which builds its credibility in that setting.

5.7 HOW SHOULD INDICATORS BE DEVELOPED?

Development of a purposeful process of continual refinement (through questioning and learning), which brings together (and explores the interactions between) production, resource economics and people, is central to the philosophy of effective indicators of performance. A challenge is to develop a framework or process where local and regional group indicators can be aggregated up to levels required for policy analysis at state and national levels. The most important contextual issue is that land managers or community be involved in, and benefit from any indicator development.

5.8 ARE INDICATORS DEVELOPED BY FARMERS RIGOROUS ENOUGH?

Scientific method generally dictates that scientists have to put numbers to variables. This often requires protocols that set out quality control and repeatability criteria. For example, measurements of soil organic carbon requires specialised procedures, often in accredited laboratories, even though spatial variability will require many samples to be analysed before confidence can be placed on the "accurate" measurement. We have witnessed a farmer showing his neighbours colour photos of water running off his farm from two storms, where the land had been managed differently. One showed muddy water leaving a bare fallow paddock, the other clean water leaving his strip crop layout. There was not doubt in the farmer audience response that what was being shown (water colour or turbidity) was valid, and no doubt the demonstration had more impact than an accurately measured "sediment concentration" in units of kg L –1 .

It appears that scientists often feel that farmer developed indicators may be less valid then theirs. Our experience is that we have seen both farmers and scientists regarding each others assumptions and methods with scepticism. There appears no good reason why farmers' observations and deductions would be any less rigorous than scientists, especially given that farmers are in a position to have rich and continuous observations as their primary data. Each group has its own set of standards and perceptions about what actually represents 'rigorous'.

5.9 ATTRIBUTES OF GOOD ENVIRONMENTAL PERFORMANCE INDICATORS

Environmental performance indicators should be relevant, practical and measurable at the farm and catchment scale. Attributes should be:

- Relevant and useful– a key attribute of an indicator is that it should be directly relevant to the land manager, to ensure there is a pathway from the observation to management action and vice versa. An indicator should provide guidance on how a resource can be better managed.
- Practical – indicators are considered practical if they are not expensive to measure and data is easy to analyse.
- Reliable – includes the technical and scientific value of the indicator and its ability to provide scientifically valid results which can be easily measured and interpreted at the farm level. There needs to be balance between what is ideal for technical (scientific) interpretation and what a land manager can measure.
- Complimentary – how the indicator articulates with existing environmental, economic and social indicators and decision making. The more uses an indicator can be put to, the more likely it will be used efficiently.

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7.0 APPENDIX 1

Natural Resources and Water
Managing Queensland's natural resources
... for today and tomorrow

RAPUP—a tool to assist natural resource impact assessment and decision making

Scope

Sub-catchment groups are seeking processes to allow them to:

- prioritise where they should place their natural resource investments
- assess the impacts of any actions they implement.

While a range of complex models are available (such as SWAT, SEDNET, EMSS, 2CSalt, IQQM and many more), they require specialist expertise to operate. They also often deal with only one issue at a time (e.g. water quality or salinity or biodiversity).

The Risk Assessment, Prioritisation and Understanding Process (RAPUP) uses local and expert knowledge and readily available GIS technology to structure decision making around priorities. It allows sub-catchment groups to assess the impacts of their actions and to understand and visualise what is happening in their local catchment.

Methods and processes

After an initial foray into high-technology models, and several visits with catchment groups, it became clear that we needed a simple framework for structuring the process of catchment prioritisation, risk assessment and impact assessment.

A lot was known about the Hodgson Creek catchment on the Darling Downs, including existing natural resource plans, and we were able to build on that existing knowledge. Available spatial data were combined, and a table of water balance and erosion values for all possible land use and land management combinations was generated. (We used the HowLeaky? program but any model or expert assessment program could be used.)

These data were used to explore the location and extent of various erosion, deep drainage and biodiversity outcomes under different scenarios for land use and management.

For example, one question asked was: 'What would be the change in water quality if all land with more than 6% slope and shallow soils that are currently being cropped was converted to pasture?'. The implications for the catchment were assessed by measuring the proportion of sediment due to erosion that reaches the end of the catchment.

RAPUP also includes a process for community engagement and biophysical analysis.

Results and achievements

The RAPUP process has been piloted in the Felton valley, a sub-catchment of Hodgson Creek on the Darling Downs. Readily available skills (within regional bodies) and GIS software and data layers were used. Enriching data layers such as land management were acquired from land use maps and local knowledge, which created a benchmark data layer for the local sub-catchment group.

The approach is simple, transparent and manageable within the resources of regional planning groups.

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