

Whatawhata Catchment Management Project: the story so far

J.M. QUINN¹, M.B. DODD² and B.S. THORROLD³

¹NIWA, Private Bag Bag 11-115, Hamilton

²AgResearch, Ruakura Research Centre, Private Bag 3123, Hamilton,

³Dexcel, Private Bag 3221, Hamilton, New Zealand.

j.quinn@niwa.co.nz

Abstract

Changes in land use and management were applied to a 296 ha catchment farm at the Whatawhata Research Centre in 2000-2001 to improve its economic and environmental performance. The area had erosion and weed reversion challenges, poorly performing beef and sheep breeding enterprises, and degraded streams. Changes included conversion of the steepest land to plantation forestry; indigenous forest restoration; intensification of the farming enterprises onto easier terrain with better pasture production; changes in stock type; poplar planting for soil stabilisation; and exclusion of livestock from streams. Significant improvements have followed. The per hectare economic surplus for the pastoral enterprise improved from 30% below industry average to 13% above. The forestry enterprise will further improve economic performance in the long-term. There were reductions in the export of suspended sediment (76%), total phosphorus (62%), and total nitrogen (33%). Water clarity has increased, stream temperature has declined and stream invertebrate indices indicate improvements in the fauna.

Keywords: agriculture, forestry, macroinvertebrates, riparian, water quality, nitrogen, phosphorus

Introduction

The sustainability of intensive pastoral farming in hill lands in New Zealand has come under increasing scrutiny in the last two decades due to a combination of economic, social and environmental pressures. To address this challenge, an integrated catchment management (ICM) project was established in 1996 within the 296 ha Mangaotama catchment farm at the Whatawhata Research Centre, Waikato, to explore a multiple goal approach to the management of North Island hill land. The approach involved the integration of multiple disciplines (i.e. agriculture and conservation, land and water, biology and economics), the consideration of a complex sustainable development problem (i.e. sustainable hill land management), and the mutual learning of science and society (i.e. interaction of the science team with

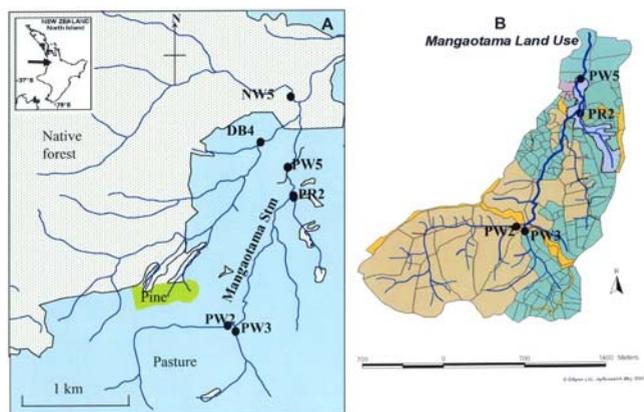
decision makers, both policy agencies and land managers). This paper summarises the response of the farm system and stream environment to land use and practice changes implemented in 2000-2001 with the aim of improving sustainability.

Methods

Study area

The catchment farm is located in the western Waikato region of the North Island (Fig. 1), and is about 60% of the size of a typical owner-operator North Island hill farm. The land ranges from easy rolling to steep hill country. It was cleared of native (podocarp-hardwood) forest about 80 years ago and revegetated in exotic pasture species. At the beginning of the project, the farm consisted of sheep and cattle breeding enterprises (~9 stock units/ha). Most of the farm is Class VI (34%) and VII (41%), with sedimentary/fulvic soils, under the New Zealand land use capability (LUC) system that indicates reducing versatility on a scale of I to VIII. The remainder is mainly Class V (19%) with ash/alvic soils. Climate is wet and mild, with average annual rainfall of 1608 mm and temperature of 13.3°C. The headwaters rise in steep hills (max elevation 342 m asl) and elevation drops to 60 m

Figure 1 Maps of study area showing (A) initial land use before 2000 and locations of key monitoring sites and stream channels, and (B) detailed stream network and land use in the Mangaotama catchment after ICM changes in 2000, with dark and stippled areas indicating pine plantations and conservation forest and lighter areas indicating pasture.



asl at the PW5 weir (Fig. 1A) where the mean discharge is 43 L/s.

The Whatawhata ICM Project

The ICM project was established in 1996 involving a group representing farmers, local government, Maori landowners, Whatawhata farm staff and researchers from several disciplines who developed the vision of a “well-managed rural hill country catchment” (Quinn *et al.* 2000). Scenarios were developed to forecast the likely effects on key indicators of different management practices (e.g. Collier *et al.* 2001). The conclusion of the group, when presented with the indicator data for the current land management system, was that the catchment farm was not performing well in either an economic or environmental context and a plan was developed to make progress toward the identified goals (details in Dodd *et al.* 2003). The steepest (Class VI and VII) land in the south-west part of the catchment was generating much of the sediment erosion and provided the lowest economic returns, while the high stream density (Fig. 1B) and large paddocks made riparian fencing for stock exclusion impractical in this part of the farm. The main theme of the ICM plan was matching land use to land capability, with a secondary theme of best management practice for each land use. Land use change in the catchment and associated management practices included (Fig. 1B):

1. Afforestation of 153 ha of mainly steep land (60% class VII, 18% class VI and 22% class V or lower) with pine (*Pinus radiata*) at 1200 stems/ha, leaving 10 m wide riparian margins on either side of all perennial streams unplanted for natural regeneration to scrub and forest. A harvest plan was drawn up to minimise harvesting impacts on erosion and streams. Analysis of forestry investment in the steeper land showed promise of much greater long-term profits, with additional benefits in reducing erosion and improving water quality. For individual landowners the issues of cashflow during implementation and farm scale need to be addressed.
2. Intensification of pastoral farming on the better contoured land. This involved a shift from breeding ewes and cows to high performance Finn-cross breeding ewe flock with Friesian-cross bulls purchased at 6 months old in autumn and sold at 18 months before their second winter. Best management practice included fencing cattle out of streams and planting poplars (approx. 1000 poles) for soil conservation on erosion prone areas still in pasture. However, there was increased tactical use of nitrogen (as urea) fertiliser to meet feed requirements of the bull beef enterprise in winter and early spring (e.g. 40 kg N/ha applied to 7 ha in May 2000). Reactive phosphate rock and sulphur-

enhanced superphosphate were applied annually in autumn by fixed wing aircraft at 24 kg P and 30 kg S /ha/yr.

3. Protection and enhancement of native forest fragments by pest control (mainly targeting possums and rats), fencing from livestock access and supplementary planting. An existing 5 ha of riparian forest were extended with a further 7 ha planted with ~ 30 species of native shrubs and trees at 2500 stems/ha.

Under a commercial owner-operator farm scenario, the changes described would be likely to take place over an extended period (~30 years) as farm cash flow allowed. This was the basis on which the scenarios were developed. However, for the purposes of the research project, the catchment group chose to implement these over a period of <2 years, commencing with poplar pole plantings in 2000, and the forestry and conservation plantings in 2001. The livestock enterprise changes were phased in to accommodate the tree planting activities, so that the 2001-02 financial year was the first fully under the new regime.

All financial data associated with the implementation of the new land use plan were recorded by the farm manager. These included the one-off investment expenses associated with construction of new fences, pine tree planting, poplar planting, indigenous forest restoration and livestock purchases. Offset against this was the revenue from disposal of livestock no longer required, i.e. the Romney breeding ewe flock and Angus breeding cow herd.

Water flow and temperature were measured at 15-minute intervals at the Mangaotama catchment weir at PW5 and weirs on the adjacent catchments with mixed land use (DB4) and native forest (NW5) (Fig. 1A). Water quality was monitored monthly at nine sites, including those in Figure 1A, as described in Quinn and Stroud (2002). Water samples were collected at the three catchment outlet weirs (PW5, DB4, and NW5, Fig. 1) from August 1996 to August 1997 for measurement of loads of sediment, nitrogen, phosphorus and dissolved organic carbon (Quinn & Stroud 2002). Samples were also collected at the Mangaotama weir (PW5) during the previous year (August 1995-August 1996) and from September 1998 to September 2005 (methods as in Quinn & Stroud 2002). Equipment failures resulted in a gap in the data from April to July 2003, and we assumed that average sediment and nutrient concentrations during this period were the same as during the rest of the 2002-2003 monitoring year to calculate loads for that year. Water clarity (horizontal black disk visibility) was measured monthly from April 1995 to August 2007. Stream invertebrate communities were assessed at sites in the catchment and adjacent reference streams (Fig. 1A) quarterly (in June, September, December and March)

from June 1995 to March 2002, and then twice yearly (September and March) until September 2005. Ten random invertebrate samples were collected with Surber samplers (0.04 m², 250 µm mesh) and combined to make a single sample per site that was preserved with isopropyl alcohol for analysis. In the laboratory, these samples were sorted, identified to the lowest practical level and counted. Data were used to calculate the Macroinvertebrate Community Index (MCI, species present weighted by their pollution sensitivity, Stark *et al.* 2001).

Results and Discussion

Pasture growth and livestock performance

Pasture production averaged 10 000 kg dry matter/ha/yr from 2000-2004 compared with 8400 kg dry matter/ha/yr in 1998-99. This slight increase was in line with predictions based on changing the balance of the pastoral enterprise towards a higher proportion of LUC Class V or lower land, as well as the tactical use of urea. The new pastoral enterprise is characterised by a slightly increased stocking rate (10 SU/ha, c.f. 9 previously) and slightly higher sheep:cattle winter SU ratio (65:35, c.f. 60:40), reflecting the focus on the more productive land classes and the changes to the cattle enterprise. On a per hectare basis, the key animal productivity parameters of the sheep and cattle enterprises have shown a marked improvement compared with the original farm system. Annual lamb liveweight (LW) productivity has increased from 116 kg LW/ha under the old system to an average over the 4 years in the new system of 203 kg LW/ha, representing an increase of 75%. Ewe mating weights and lamb weaning weights have shown little change, but lamb production at weaning has improved from 109% to 127% of ewes mated. Wool productivity has also increased from 23.7 kg/ha to an average of 27.3 kg/ha, an increase of 15%. Beef productivity has also increased from 86 kg LW/ha under the old farm system to an average of 209 kg LW/ha over 4 years under the new system, representing an increase of 143%.

Costs of implementation and farm economics

The net cost of implementation of the ICM plan in the first year was approximately \$260 000 (tree planting, fencing and stock purchases less stock sales). This was dominated by the cost of tree planting, with the 7 ha of native trees (19 700 plants at \$142 400) costing ~80% of the cost of the 153 ha of pines (\$178 200). Additional tree management costs anticipated in the first 10 years amount to an additional \$340 000, hence the total cost of implementing the land use changes is likely to amount to nearly \$600 000. In 1998-99, before the ICM changes were in place, the annual economic farm surplus (EFS, excluding owner-operator management wage) of the 296

ha pastoral farm was well below the industry average (\$94/ha c.f. \$131/ha for the MWBES North Island hill county farm survey data, MWBES 1999). From 2001-2004 the now smaller (131 ha) pastoral enterprise had an average annual surplus of \$285/ha, 13% above that of the industry average (\$253/ha, MWIES 2001-04). The lift in the industry average reflects increased product returns. The lift in catchment pastoral farm performance (relative to the industry average) came from increased per head performance and from removing (by afforestation) the steeper land from the pastoral farm that carried less stock and had high management costs (mainly for weed control and infrastructure maintenance). At farm scale, the annual surplus of the farm increased from \$27 824 in 1998-99 to \$37 355 from 2001-04. The financial returns on the half of the farm planted in pine forest are difficult to predict because they will depend on timber prices and extraction costs when the trees mature at about age 27 yr. A study in 1999 predicted an average annual cash flow after logging commenced of \$187 000/yr if the area had been planted and harvested progressively (c. 5 ha/yr) (Quentin Way, unpublished report). In the meantime, there are costs to establish and maintain the planted forest (see above) that would likely require a farmer to obtain input from an outside investor to maintain an adequate financial return.

Water quality

Rapid and significant reductions occurred in loads of sediment (average down 76%, ANOVA $F_{1,8} = 3.5$, $P=0.0079$) and phosphorus (down 62%, $F_{1,8} = 13.2$, $P=0.0083$) at the lower Mangaotama weir (PW5) after implementation of the land management changes (Fig. 2). Average flows were very similar in the years before and after changes, indicating that the sediment and P responses were due to land use changes rather than climatic variations. Pine afforestation was expected to reduce erosion as the trees develop into a forest, but the rapid reductions observed suggest that the main effects were due to stock exclusion after afforestation of the steepest part of the catchment and riparian fencing of the streams in areas that remained in pasture. Monthly measurements of water clarity at PW5 show a significant positive trend over time since ICM changes were made ($r^2=9\%$ $P=0.007$), whereas no trends were apparent at the native or mixed land use reference sites.

Total nitrogen load also declined after ICM changes, though relatively less than the total phosphorus load (Fig. 2), due to the significant contribution of nitrate to total nitrogen (Fig. 2). Total Kjeldahl N (TKN) had a similar level of reduction to TP (65 & 62% respectively) after the ICM changes, indicating that the organic nitrogen is lost largely through surface flow processes. However, nitrate changed little and total N load only declined by

Figure 2 Annual mean flow and loads of suspended sediment (SS), total phosphorus (TP), dissolved reactive phosphorus (DRP), total nitrogen (TN), total Kjeldahl nitrogen (TKN), nitrate, and dissolved organic carbon (DOC) at the Mangaotama weir (site PW5 Fig. 1A).

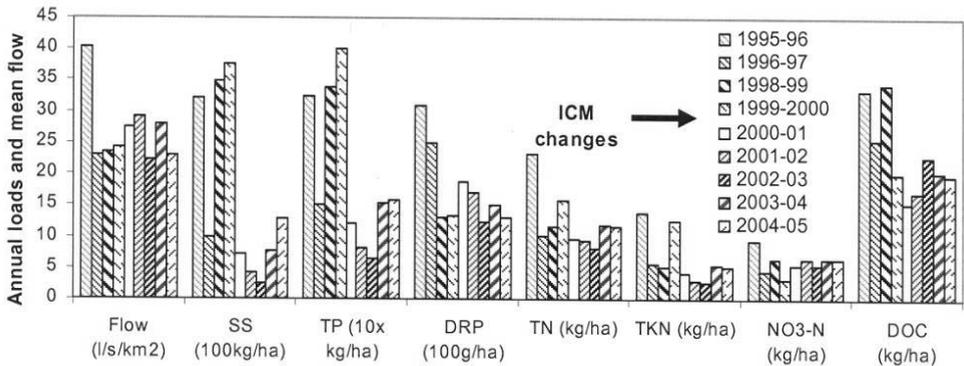
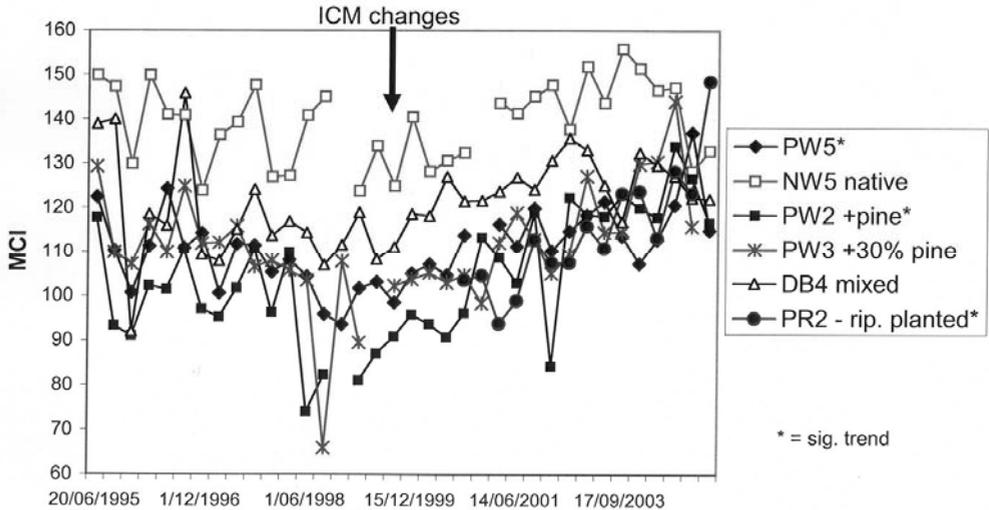


Figure 3 Trends in macroinvertebrate community index (MCI) at four Mangaotama stream sites and adjacent mixed land use (DB4) and native forest (NW5) sites (see Fig. 1A) over 11 years, before and after ICM changes.



33%. Radio-isotope studies at the 9 ha Pukemanga subcatchment at Whatawhata indicate a mean groundwater residence time of 9 years (Stewart *et al.* 2007). This suggests that it may be some time yet before the effects of reduced nitrate leaching to groundwater in areas planted in pines flow through to reduced groundwater nitrate concentrations and subsequent inputs to the streams. Riparian buffers in areas remaining in pasture are also expected to reduce nitrogen inputs from surface runoff and groundwaters. Ongoing monitoring will determine the net effect of these changes.

Water temperatures declined progressively at PW5 after ICM changes were made, indicating increased shading of the stream channel. The difference in annual mean temperature between PW5 and the native reference (NW5) declined from 6.5°C in 1999 to 1.4°C in 2004

and corresponding differences in annual maxima declined from 6.7°C to 3.8°C.

Macroinvertebrates

The macroinvertebrate community index (MCI) showed statistically significant positive trends over the period from 1995 to 2006 (Fig. 3) at the sites downstream of riparian planting (PR2, $r^2=0.75$, $P<0.0001$), pine afforestation (PW2, $r^2=0.36$, $P=0.0002$), and near the catchment outlet (PW5, $r^2=14\%$, $P=0.025$). In contrast, there were no statistically significant trends at the native forest or mixed land use reference sites (NW5 & DB4) or at PW3 that had 30% of its catchment afforested in pines and the remainder in pasture.

Mean MCI at PW2 and PW5 during the two most recent surveys of September 2005 and March 2006 were

122 and 126 respectively, representing 26% and 18% increases over their mean values before ICM changes.

Concluding Remarks

Farmers and resource managers need well-documented case studies to underpin sustainable land management decisions. This study demonstrated economic and environmental benefits from applying an ICM approach to define and meet multiple goals for sustainable use of hill land resources by a combination of better matching of land use and livestock enterprises to land capability and riparian management. Its findings have broad application to management of large areas on hill-lands in New Zealand. Different aspects of response to ICM implementation occur at a range of time scales and this should be recognised in the design of monitoring schemes.

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