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Marine and Tropical Sciences Research Facility Milestone Report, June 2008

Program 7: Halting and Reversing the Decline of Water Quality

Project 3.7.5: Socio-economic constraints to and incentives for the adoption of land use and management options for water quality

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Summary

This milestone report provides the final report on the long term effectiveness of best management practices (BMPs) for water quality improvement in the Dry Tropics including an assessment of the implementation costs of land use and management options for water quality improvement, a summary of communication activities undertaken over this reporting period, and a plan for completion of out year activities.

A summary is given regarding the approach used for the cost-effectiveness assessment of land use management options for water quality improvement in the Dry Tropics of the GBR region in Australia, and results are presented for management options for sugarcane production.

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Project Outputs / Milestones

Objective	Targeted Activity	Due Date
a	Assessment of the long term effectiveness of BMPs for water quality for the most important production systems in the Dry Tropics, taking into account the impact of biophysical trends and fluctuations, and including (i) a progress update on the assessment of the implementation costs of current and future land use and management options for water quality improvement, based on literature review and cost-benefit analysis in the Dry Tropics, (ii) final summary of communication activities undertaken through current project year, and (iii) plan for completion of out-year activities, including objectives (b)-(e).	10 June 2008
b	Framework for a spatially explicit model that allows for the assessment of sustainable land use and land management patterns in GBR catchments – in conjunction with Project 2.5i.4.	1 December 2007

Project Results

Description of the results achieved for this milestone

This section provides (i) the final report on assessment of the long term cost-effectiveness of Best Management Practices (BMPs) for water quality improvement for the sugarcane production system in the Dry Tropics, taking into account the impact of biophysical trends and fluctuations, and (ii) a framework description for a spatially explicit model that allows for the assessment of sustainable land use and land management patterns in GBR catchments – in conjunction with Project 2.5i.4.

Final report on the assessment of the long term cost-effectiveness of BMPs for the most important production systems in the Wet Tropics

1. Introduction

The Great Barrier Reef (GBR) is internationally recognised for its outstanding natural, social, cultural and economic values. Concern about the health of the GBR has led to the development of the Reef Water Quality Protection Plan (RWQPP) (2003). The RWQPP was developed with the goal of halting and reversing the decline in water quality entering the reef within ten years and will require industries in catchments draining into the GBR lagoon to meet water quality targets. Agriculture is an important land use in GBR catchments and has been identified as an important source of diffuse pollution (Brodie *et al.* 2003). Meeting water quality targets is thus likely to require changes to the management practices traditionally employed on these farms.

The most abundant agricultural land use in the Lower Burdekin sub-catchment area is sugarcane (QLUMP, 2004). The Burdekin is Australia's largest sugarcane producing region with over 70,000 ha of sugarcane harvested annually, yielding approximately 8 Mt of cane (22% of Australia's total production) (Thorburn *et al.* 2008). In common with other sugarcane producing regions, nitrate is one of the priority water quality contaminants originating from sugarcane cultivation (Mitchell *et al.* 2007). Sugarcane production in the Burdekin region stands out from other crops and regions because it is fully irrigated and has the highest nitrogen (N) fertiliser application rates of any sugarcane producing region in Australia (Thorburn *et al.* 2008).

The objective of this report is to explore efficient water quality improvement targets, associated industry land management arrangements and incentives for industry adoption of BMPs for water quality improvement by the sugarcane industry in the Lower Burdekin. In this report we:

- Determine the financial-economic consequences of BMP implementation in sugarcane production;
- Determine the effectiveness of these BMPs in reducing dissolved inorganic nitrogen via leaching and runoff.

The structure of this report is as follows. Section 2 describes the methodology applied in this study, which links production system simulation models, water quality models and cost-benefit analysis to assess the plot level financial-economic cost-effectiveness of management practices in sugarcane production. In Section 3 results are presented and analysed for the identified management practices, thereby looking at annuity gross margins and average annual water pollutant deliveries. Finally, Section 4 summarises key results and offers concluding remarks and observations.

2. Approach to long term effectiveness analysis of industry 'best management practices'

There are different ways to manage agricultural land, i.e. ways in which soils are prepared or crops are treated. To analyse the long term effectiveness of these so called Management Practices (MPs) for water quality improvement, we apply an approach that uses (1) production system simulation models, and (2) a hydrological model in combination with (3) sound cost-benefit analysis (see Roebeling *et al.* 2005). To be more specific:

- 1) The effects of different management practices on sugarcane production and their contribution to dissolved inorganic nitrogen (DIN) delivery (via runoff and deep drainage leaching) at the plot level are estimated using the Agricultural Production System Simulation model APSIM (see for example Robertson *et al.* 1995; Keating *et al.* 1999, 2003);
- 2) Physical nutrient sinks (denitrification) are estimated at the sub-catchment level using the water quality model SedNet/ANNEX (Fentie *et al.* 2006) to determine nutrient delivery to the river mouth;
- 3) The financial-economic consequences of management practice implementation are determined at the plot level using standard cost-benefit analysis (Zerbe and Dively, 1994).

To perform a regional (spatial) analyses these three information components feed into the Environmental Economic Spatial Investment Prioritisation (EESIP) model (based on Roebeling *et al.* 2006). The EESIP model integrates these information components and can be used to (i) explore (cost) effectiveness of industry specific BMPs for water quality improvement on a regional level (see Section 3.2), and to (ii) assess the effectiveness of price policy instruments in promoting industry BMP adoption. In this report the first will be addressed.

2.1 Sugarcane cropping systems model APSIM

A review of sugarcane MPs for water quality improvement in the Burdekin catchment has been conducted by Thorburn and others (2007). This review was developed collaboratively between the Burdekin Dry Tropics NRM, BSES Ltd, BBIFMAC, ACTFR, CSIRO and Cane Growers in support of the Reef Water Quality Protection Plan and the Burdekin Dry Tropics Water Quality Improvement Plan.

Sugarcane input-output data for different management practices (MPs) are generated using the sugarcane cropping systems model APSIM. APSIM simulates, for a uniform block of cane, per hectare long term production output information such as cane yield, N losses via deep drainage, N losses via runoff, etc. Model simulation results are determined by information on soil factors, management factors and fertiliser use, genetic factors such as sugarcane variety, and climatic factors like rainfall, solar radiation and temperature.

In his review, Thorburn *et al.* (2008) used APSIM to explore possible management strategies to reduce long-term N losses at the experimental sites. The management strategies were classified according to farming systems and N fertiliser amounts (Table 1). These management classes were determined from consultation with farmer groups and regional extension staff to categorise the range of management practices in the region. Each class, E to A, combined decreasing tillage intensity with reduced N application rate. Classes E to C are commonly practiced in the region, while Class B is similar to the currently promoted “best practice” and Class A is the best practice currently under experimental investigation (Thorburn *et al.* 2008).

Long term simulations of these management classes were undertaken for three experimental sites to quantify the potential change in nitrate-N lost through runoff and deep drainage (Thorburn *et al.* 2008).

Table 1: Fertiliser and tillage management within Management Classes.

Management Class (code)	Tillage System	N Fertiliser System
E (CW-V)	Bare fallow with high levels of tillage for crop destruction and weed control (8 passes), seedbed preparation (6 passes) and crop establishment (6 passes).	330 kg/ha on Plant cane, 400 kg/ha on Ratoon cane
D (BC-M)	Bare fallow with conventional tillage practice (as for E but number of passes halved, except for weed control).	190-210 kg/ha on Plant cane, 270 kg/ha on Ratoon cane
C (BB-c)	Bare fallow (crop destruction as for D), then zero tillage (including planting).	Traditional BSES recommendations (Calcino, 1994)
B (BB-6)	As for C.	'Six easy steps' (Schroeder <i>et al.</i> 2005)
A (NBc)	Legume (containing low N amounts) cover crop in fallow with no tillage following planting, then as for C.	'N replacement' adjusted for legume (Thorburn <i>et al.</i> 2007)

2.2 Water quality model – SedNet/ANNEX

The hydrological model SedNet/ANNEX (Sediment River Network model/Annual Network Nutrient Export) is used to estimate the net contribution from MPs to total annual DIN (t/yr) delivery to the coast. In this report the focal priority pollutant is Dissolved Inorganic Nitrogen (DIN) in runoff and deep drainage leaching from cropping systems, since there is a reasonable assumption that sediment losses from irrigated fields are very low in the Burdekin (Ham, 2007 in Thorburn *et al.* 2008). Furthermore, sugar cane production near the mouth of the Burdekin is predicted to be the largest contributor of dissolved inorganic nitrogen loads exported to the GBR (Fentie *et al.* 2006).

A nutrient budget is an account of the most important sources and sinks for physical nutrients (Young *et al.* 2001). Sources of nutrients include sediment associated nutrients, dissolved organic and inorganic nutrient loads in runoff water, and point sources of nutrients. Sinks for nutrients are associated with, i.e. sediment deposition and denitrification. Total nutrient delivery at the river mouth is the net result of the above processes in upstream internal watersheds and connecting gullies, streams and rivers (Roebeling *et al.* 2006). SedNet/ANNEX Short Term Modelling simulation results (from Sherman, B. in Fentie *et al.* 2006) show that in all of the sub catchments in the Lower Burdekin the amount of N lost via nutrient sinks is very low (between 0% and 1%). Therefore, in this study we assume 100% DIN delivery to the river mouth from plot level runoff. Based on Brodie and Bainbridge (2008), approximately 17% of DIN leached via deep drainage ends up in the river mouth. Further research is recommended to validate the relationship between the amount of DIN available for runoff, deep drainage leaching and net delivery to the coast in the Lower Burdekin.

2.3 Cost-benefit analysis

All analysed MPs were simulated for more than one year. Values that occur later in time are worth less at present than those occurring earlier in time and therefore a time discount rate r is used to value future costs and benefits in present-day terms. To compare MPs with

varying life-spans, annuities of net present values (NPVs) are calculated for each of them. Using the NPV approach (Equation 1) in combination with the capital recovery factor to determine the annuity A (Equation 2) produces correct financial decisions in all cases (Zerbe and Dively, 1994).

The net present value (NPV) of a project is defined as the discounted sum of differences between benefits B_t and costs C_t that are attributable to the installation of the project and that occur in each period t over the entire lifetime of the project T (Zerbe and Dively, 1994).

$$NPV = \sum_{t=0}^T \frac{B_t}{(1+r)^t} - \sum_{t=0}^T \frac{C_t}{(1+r)^t} \quad \text{Equation 1}$$

where r is the time discount rate. The NPV rule states that investment in a project should take place in case $NPV > 0$. To be able to compare projects with different lifetimes T , net present values are converted into annuities (Schipper *et al.* 2000). The annuity A of a net present value is calculated using the capital recovery factor, which is given by (Zerbe and Dively, 1994):

$$A = NPV \left[\frac{r}{1 - (1+r)^{-T}} \right] \quad \text{Equation 2}$$

where T is the project lifetime (generally in years). An annual amount A needs to be obtained at the end of each period over the life span of the project T to recover the net present value NPV at the end of the T th period at discount rate r (Zerbe and Dively, 1994).

For the calculation of costs and benefits of MPs, the input, output and machinery use prices are based on information from QDPI&F's Farm Economics Analyses Tool (FEAT), based on Lower Burdekin case studies (M. Poggio, QDPI&F, *pers. comm.*). The time discount rate r is set at five percent per year (Roebeling *et al.* 2006). Taxes, non-production system specific fixed asset depreciation and maintenance costs, and capital costs are not considered in the gross margin figures at the plot level.

2.4 Spatial environmental economic analysis – EESIP

To explore the (cost-) effectiveness of the specified MPs to achieve water quality targets spatially (in the whole of the studied region), we use the EESIP model which is a spatial environmental-economic approach that integrates a land use and value chain model with a hydrological model (Roebeling *et al.* 2006).

In this approach, land use and land management (in this case MPs) are allocated at the regional scale on the basis of which land use and management practice on a particular land unit contributes most to regional agricultural income (in this case the sugarcane growing industry), where regional agricultural income is estimated as the sum of (per ha) production value less corresponding variable spatially explicit production and transport costs for all the blocks of land in the studied area (Roebeling *et al.* 2006).

3. Long term cost-efficiency of MPs in the sugarcane production system

This chapter summarises the results of the cost-effectiveness of MPs in the sugarcane industry in the Lower Burdekin. For detailed information on the identified MPs in this study please refer to Section 2.1 of this report and to Thorburn *et al.* (2008). For the analysis of the (cost-) effectiveness of MPs in sugarcane production we will look at two indicators: annuity gross margin (in AU\$/ha/yr) and average annual water pollutant delivery (split up in DIN via runoff in t/ha/yr and DIN via deep drainage leaching in t/ha/yr). Results are analysed both at the plot level as well as a regional level.

Gross margin is defined as the production value (yield*price) minus variable input costs (i.e. labour, machinery and irrigation). It is important to note that taxes, non-production system specific fixed asset depreciation and maintenance costs (e.g. machinery, barns and sheds), and capital costs (i.e. opportunity or finance costs of fixed assets) are not considered in the gross margin figures at the plot level as these costs are determined at the farm level (Roebeling *et al.* 2006).

3.1 Plot level cost-effectiveness

In this section we describe the plot level results of the analysis of the (cost-) effectiveness of MPs in sugarcane production based on annuity gross margin (AU\$/ha/yr), DIN leached (t/ha/yr) and DIN runoff (t/ha/yr). Table 2 shows a summary of the economic and water pollution (DIN) effectiveness of management classes in the sugarcane production system, from least effective (--) to most effective (++), based on numeric information provided in Table 3.

Table 2: Economic and water pollution (DIN) effectiveness of management classes in the sugarcane production system.

Management class	Tillage System	N Fertiliser System	Gross Margin	DIN Leached	DIN Runoff
E (CW-V)	Bare fallow with high levels of tillage for crop destruction and weed control (8 passes), seedbed preparation (6 passes) and crop establishment (6 passes).	330 kg/ha on Plant cane, 400 kg/ha on Ratoon cane	(-)	(- -)	(- -)
D (BC-M)	Bare fallow with conventional tillage practice (as for E but number of passes halved, except for weed control).	190-210 kg/ha on Plant cane, 270 kg/ha on Ratoon cane	0	(+)	(-)
C (BB-c)	Bare fallow (crop destruction as for D), then zero tillage (including planting).	Traditional BSES recommendations (Calcino 1994)	0	(+)	(+)
B (BB-6)	As for C.	'Six easy steps' (Schroeder <i>et al.</i> 2005)	(+)	(+)	(+)
A (NBc)	Legume (containing low N amounts) cover crop in fallow with no tillage following planting, then as for C.	'N replacement' adjusted for legume (Thorburn <i>et al.</i> 2007)	(+ +)	(+ +)	(+ +)

Moving from high tillage levels towards a zero tillage system as well as moving towards a legume (rather than a bare) fallow are attractive from a financial-economic perspective. It will also lead to a reduction in water pollutant (DIN) delivery. Matching nitrogen application rates to crop requirements is attractive from a financial-economic as well as a water pollutant (DIN) delivery perspective.

Table 3 provides an overview of the economic and water pollution (DIN) indicators resulting from this study at the different research sites (soil type). As previously shown it is clear that on every soil type changing from management class E to management class A provides sufficient benefits both from a financial-economic as well as a water pollutant (DIN) delivery point of view. The only exception to this is soil type H, where changing from management class D to C will in fact lead to higher DIN leached to deep drainage. The results shown in Table 3 are graphically represented in Figure 1 and Figure 2 to 5.

Table 3: Economic and water pollution (DIN) indicators.

Management Class	Soil Type	DIN Runoff	Std. Dev.	DIN Leached (deep drainage)	Std. Dev.	Gross Margin	Std. Dev.
A	G	0.72	0.32	1.13	0.53	\$1,362.78	103.66
B	G	8.47	0.95	3.23	0.49	\$1,136.29	92.16
C	G	10.69	1.14	7.40	0.65	\$1,051.73	91.10
D	G	26.86	4.47	8.97	1.55	\$1,043.19	86.71
E	G	43.08	7.44	23.48	4.35	\$817.59	88.27
A	H	1.00	0.31	4.45	1.71	\$1,157.31	162.78
B	H	12.07	0.92	7.19	2.96	\$1,038.23	132.76
C	H	16.72	1.23	13.92	4.82	\$951.07	127.34
D	H	41.48	2.38	12.05	2.72	\$946.08	124.09
E	H	59.83	7.74	34.58	12.41	\$712.69	125.59
A	K	0.05	0.03	12.82	7.13	\$2,153.33	204.82
B	K	1.80	0.63	24.46	13.03	\$1,971.29	170.98
C	K	1.85	0.51	39.50	16.13	\$1,934.50	145.42
D	K	3.43	0.51	50.12	15.61	\$1,959.10	126.56
E	K	7.15	0.77	124.95	15.48	\$1,742.07	127.42
A	N	0.13	0.07	6.39	4.96	\$2,366.52	154.24
B	N	1.70	0.59	13.37	9.36	\$2,131.63	138.87
C	N	1.85	0.46	19.00	12.49	\$2,091.81	128.76
D	N	3.39	0.48	27.81	15.58	\$2,105.64	121.29
E	N	5.64	0.82	91.21	16.87	\$1,900.77	121.42

Figure 1: Gross margins of management classes A-E.

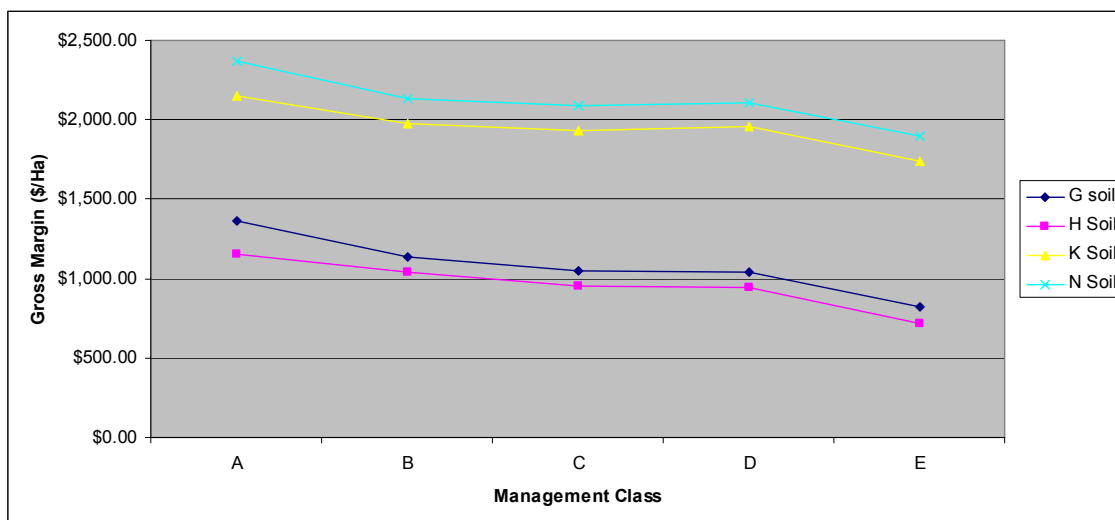


Figure 2: Plot level water pollutant (DIN/ha) of management classes A-E on a G soil.

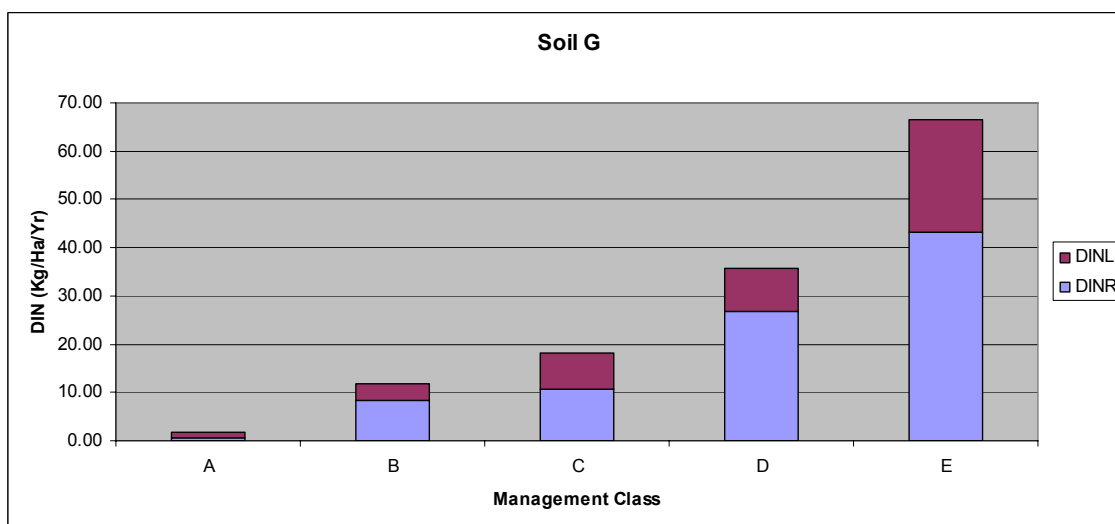


Figure 3: Plot level water pollutant (DIN/ha) of management classes A-E on a H soil.

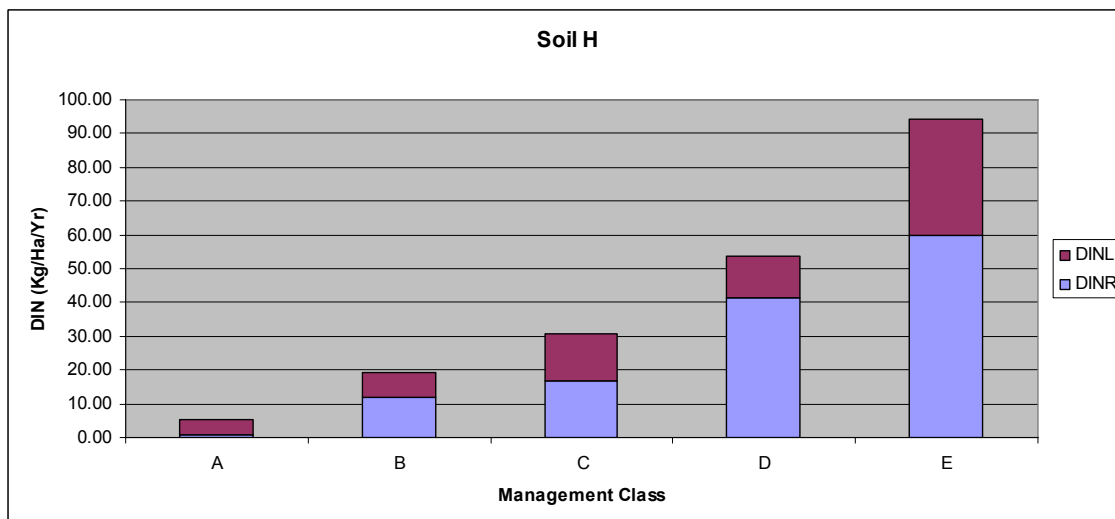


Figure 4: Plot level water pollutant (DIN/ha) of management classes A-E on a K soil.

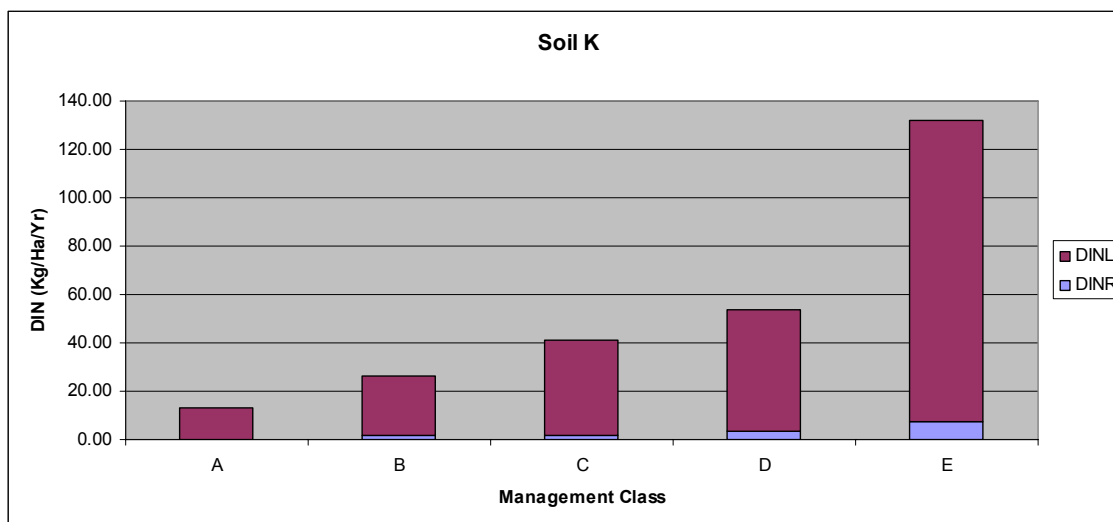
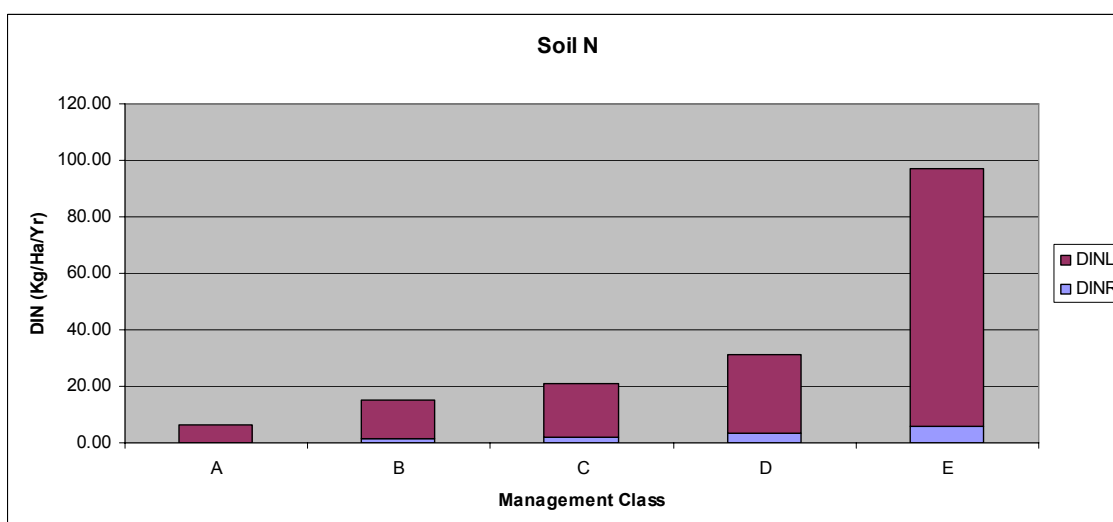


Figure 5: Plot level water pollutant (DIN/ha) of management classes A-E on a N soil.



3.2 Regional level implications

In this section we describe the regional level results of the analysis (EESIP, see Section 2.4) of the cost-effectiveness of MPs in sugarcane production based on annuity gross margin (AU\$/ha/yr), DIN leached (t/ha/yr) and DIN runoff (t/ha/yr). Extra information is given on Total DIN (DIN from runoff plus DIN from deep drainage leaching) and fertiliser use (t/yr). Several scenarios are used to perform the analyses. First, we determine the base scenario, second, we look at the different MPs described in Section 2.1, third, the optimal distribution of MPs is determined and finally, four steps to reach the optimal situation (highest regional sugarcane growing income and lowest water pollution) are described.

3.2.1 Base scenario

The percentage of farmers currently practicing the different MPs in the Lower Burdekin area was estimated from farmer surveys and local knowledge (Thorburn *et al.* 2008), as listed in Table 4. The Delta area contains a mix of K and N soils. Since the precise allocation of these

soils is uncertain, in the regional spatial analysis only the information on K soil is used to represent the Delta area. The G and H soils are found in the BRIA area (QLUMP, 2004).

Table 4: Percentage of farmers in each fertiliser management category by area.

Management Class	Soil K	Soil G	Soil H
E	12%	10%	10%
D	63%	50%	50%
C	18%	30%	30%
B	7%	10%	10%
A	0%	0%	0%

Figure 6 to 12 on the next pages provide spatial information on the current situation (based on EESIP simulations) regarding:

- Current distribution of MPs (based on Table 4);
- Distance from each block of land to the nearest mill (m);
- Cane yield (t/ha/yr);
- DIN runoff (kg/ha/yr);
- DIN leaching (kg/ha/yr);
- Total DIN (kg/ha/yr) (the sum of DIN runoff and DIN leaching); and
- Fertiliser use (kg/ha/yr).

Associated numbers are presented in Table 5.

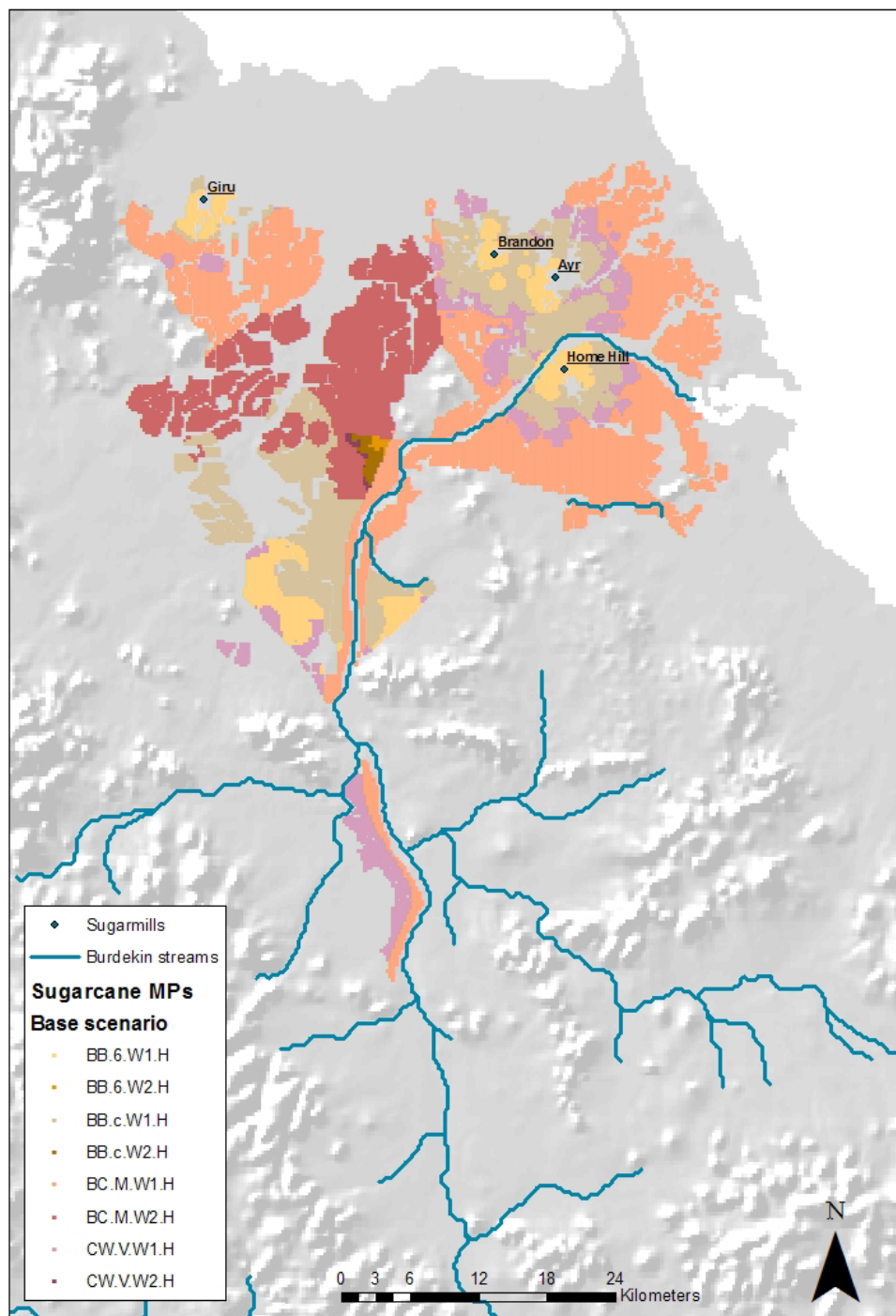


Figure 6

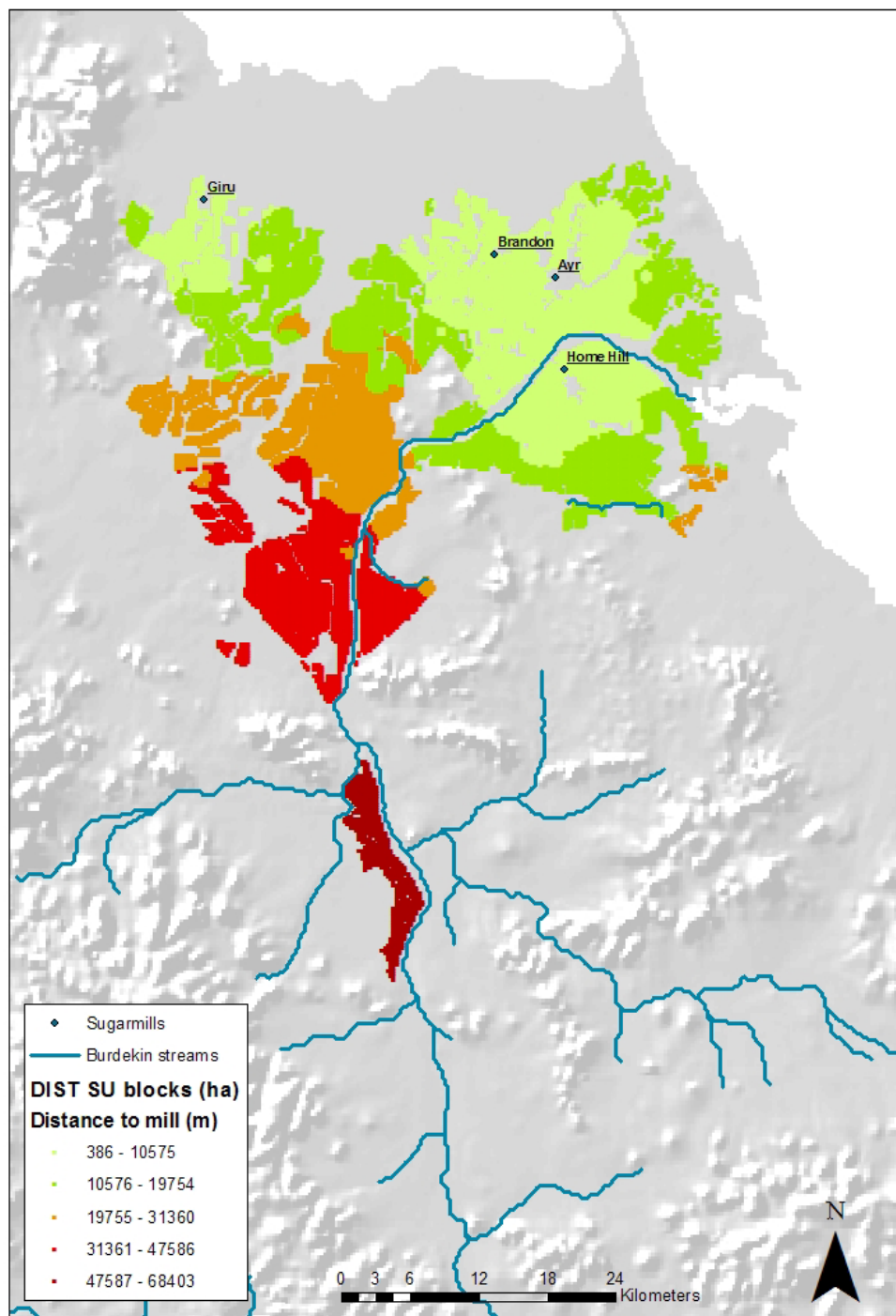


Figure 7

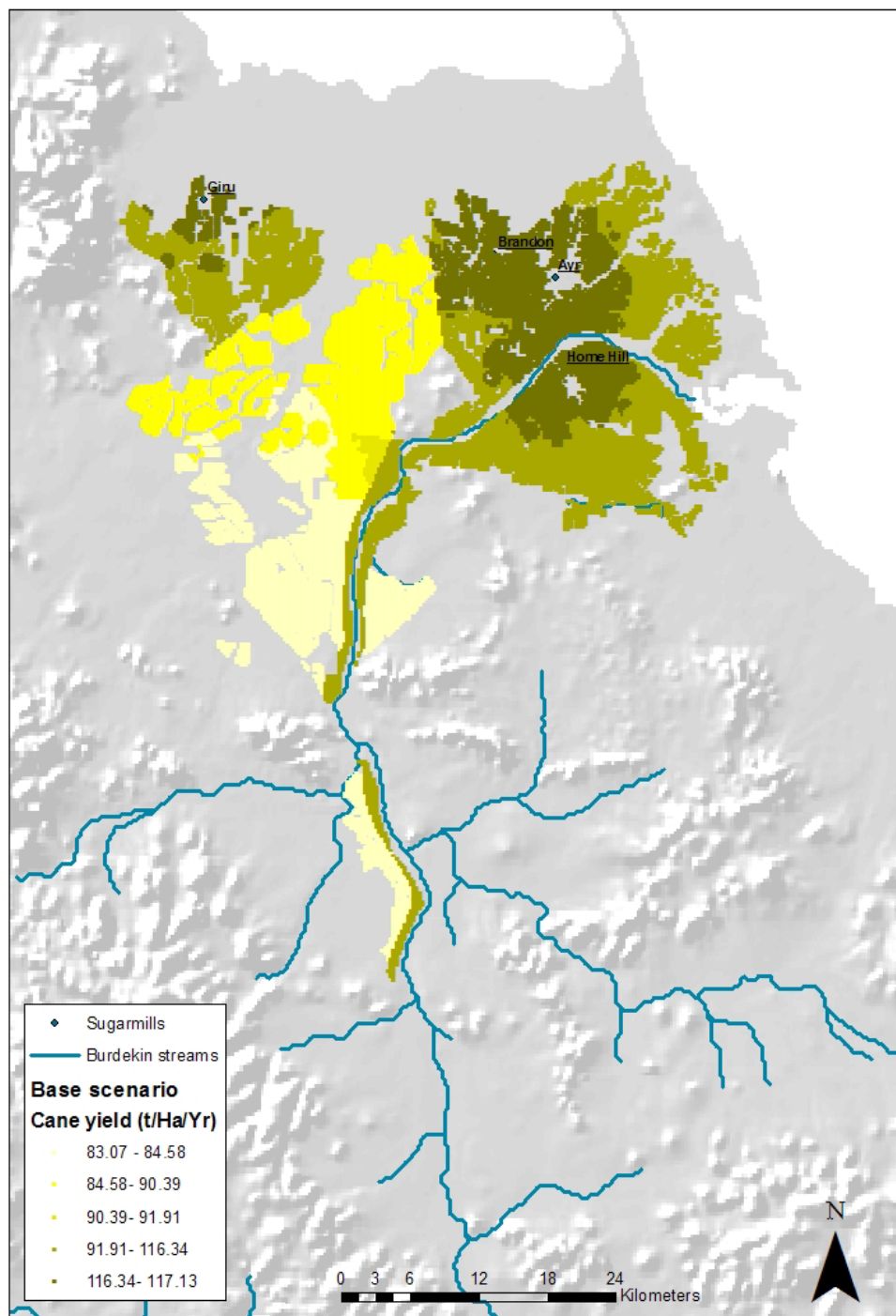


Figure 8

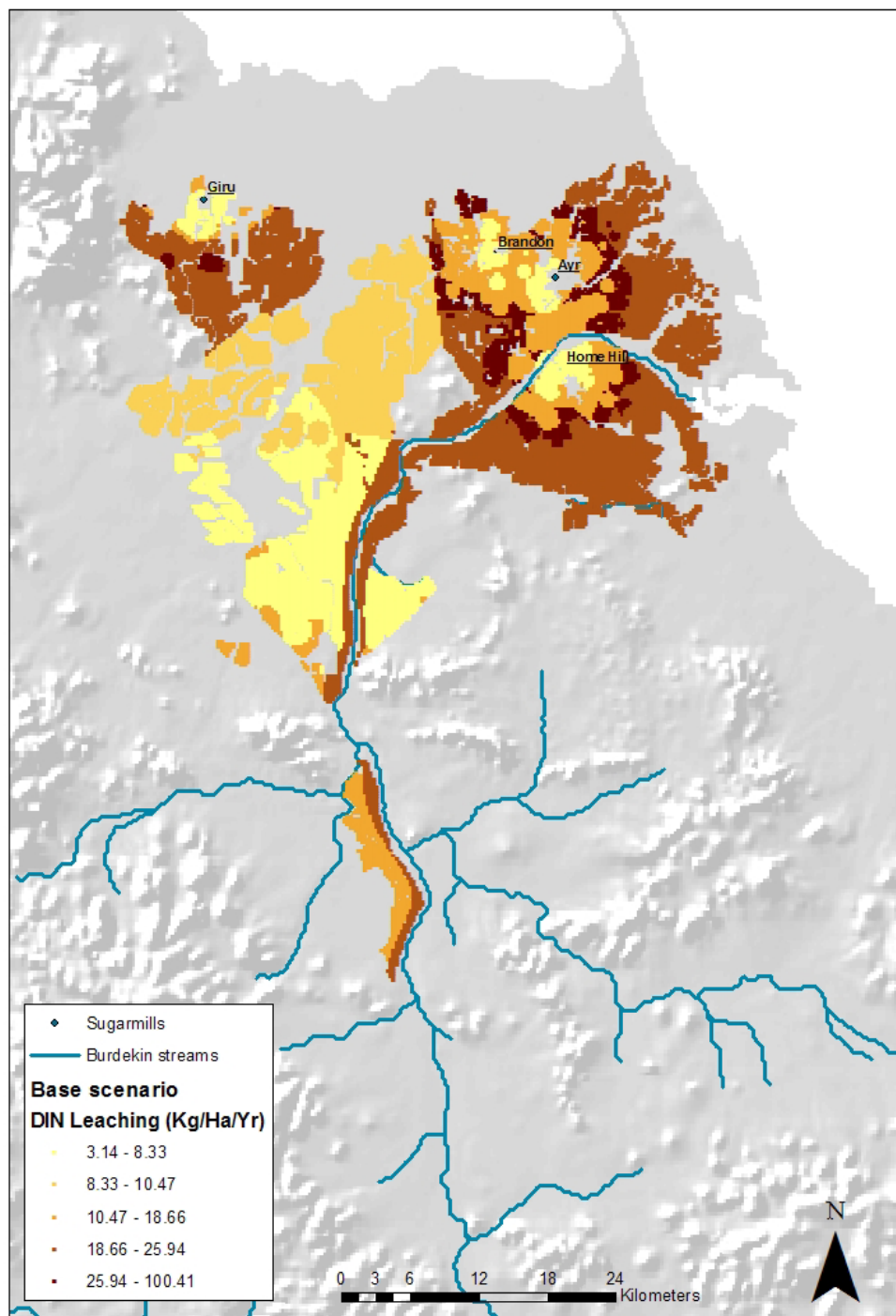


Figure 9

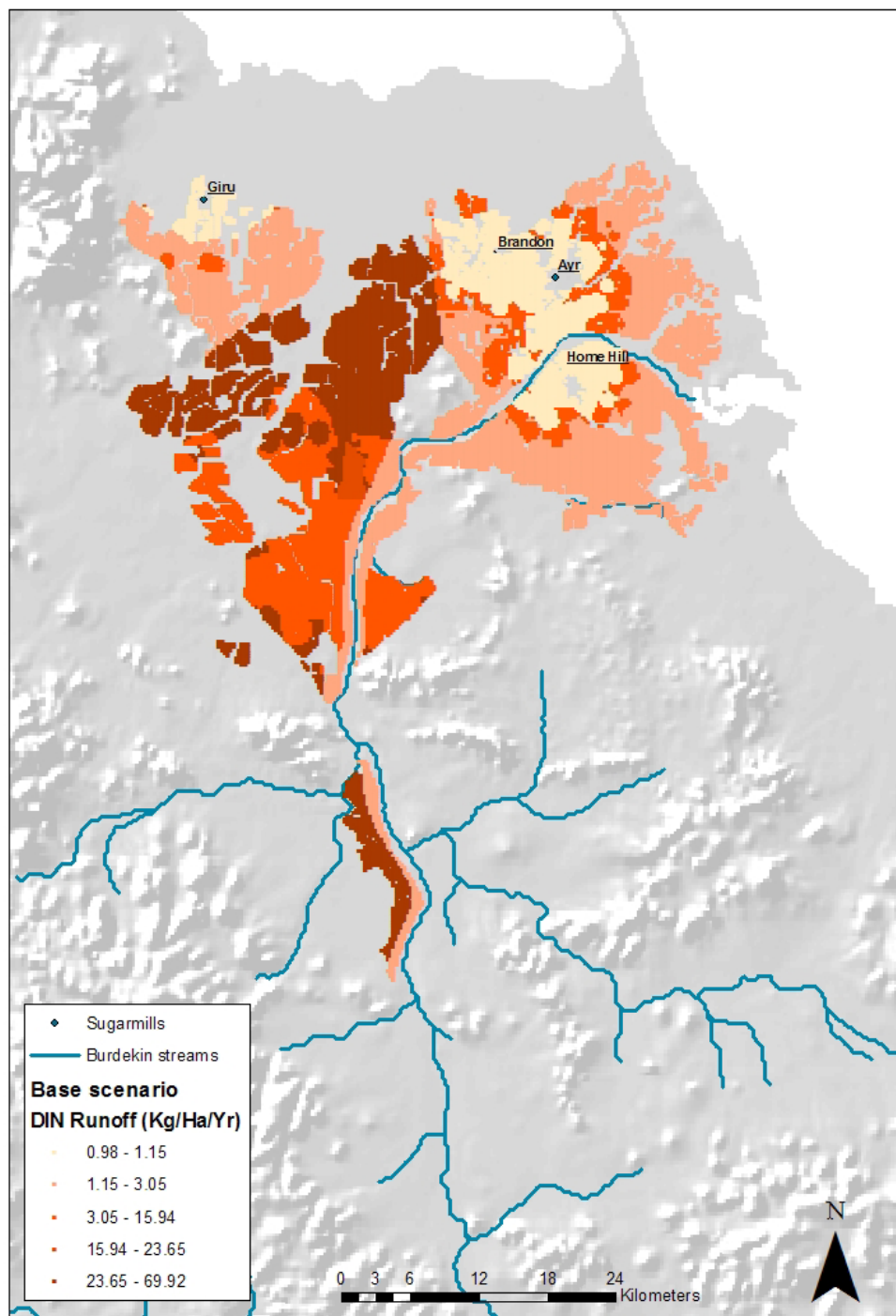


Figure 10

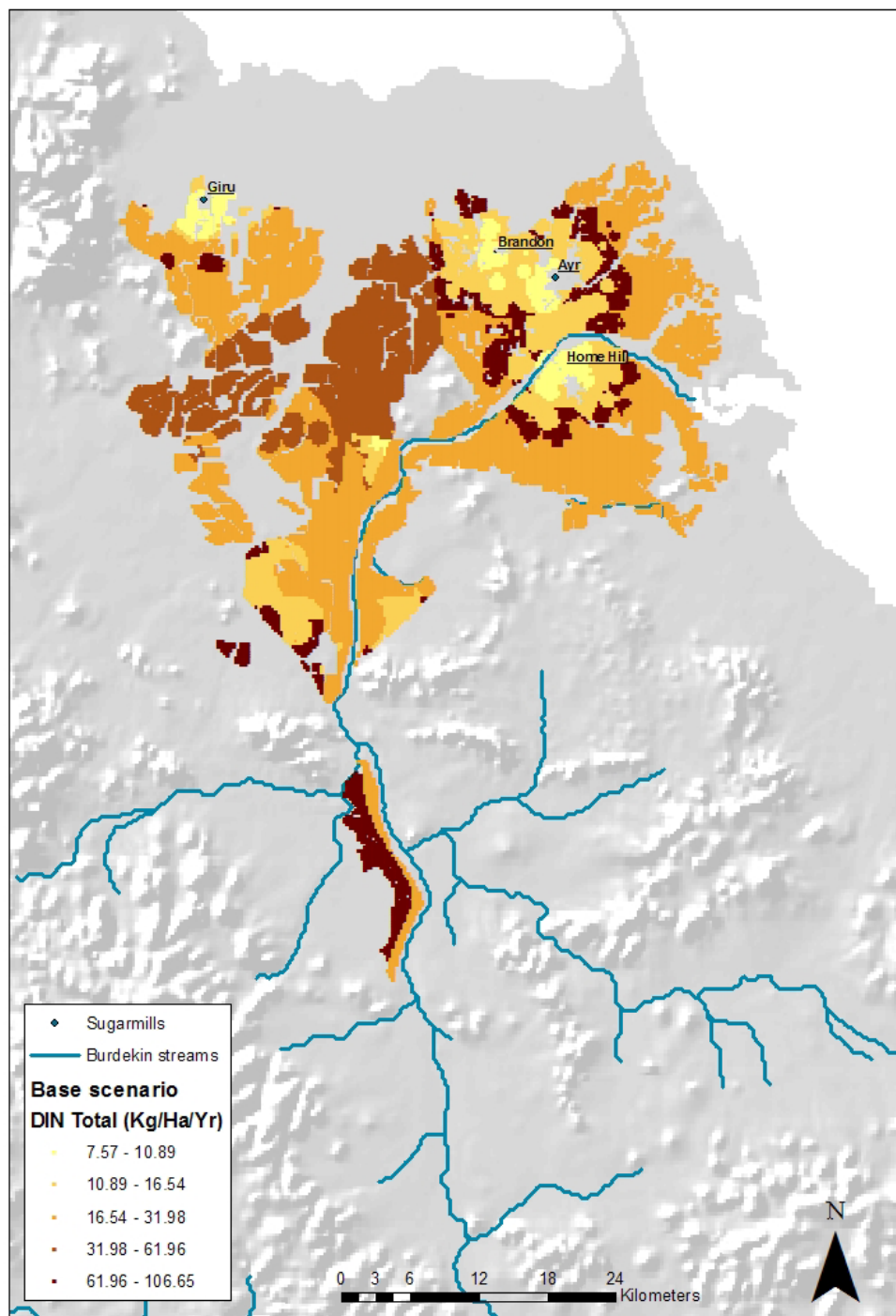


Figure 11

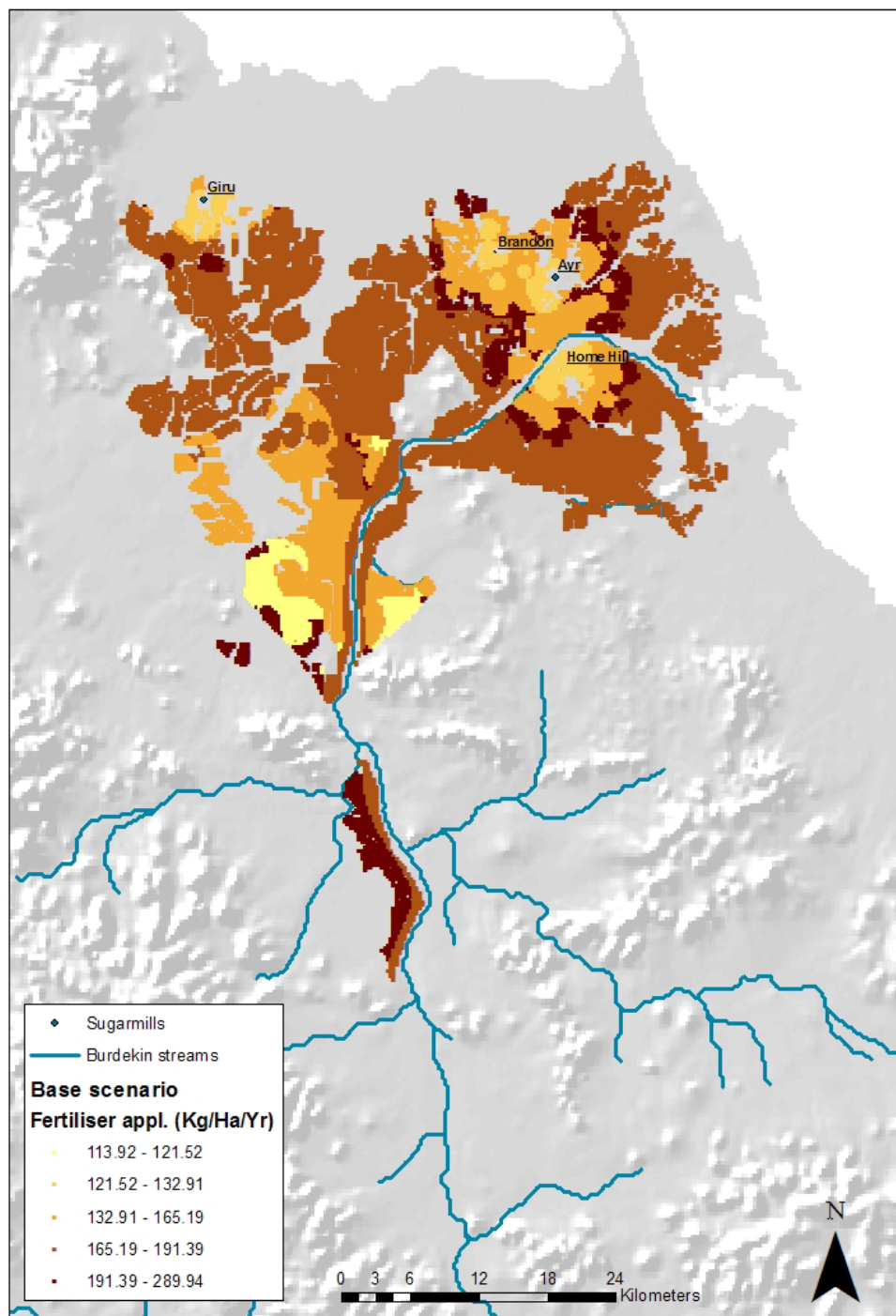


Figure 12

Table 5: Economic and water pollution (DIN) indicators for the base scenario.

Scenario	Base scenario
Objective	142.77
Area (Ha)	91265.63
Cane Production (1000t/yr)	9575.78
DIN Runoff (t/Yr)	1283.38
DIN Leached (t/Yr)	2096.45
DIN Total (t/Yr)	3379.84
Fertiliser Use (t/Yr)	17428.50

From Figures 6 to 12 it is clear that the highest yields are achieved in the Delta area and that in contrast to DIN leaching, DIN runoff is highest in the BRIA area. Since the base scenario is based on a relative distribution of MPs, the EESIP model allocates the MPs with the highest yields nearest to the mill due to increasing transport costs (\$/kg/km), based on the von Thünen (1826) model of farm price, land use and land rent.

3.2.2 Scenario 2: Analyses of management classes A-E.

In this section all management classes described in Section 2.1 are analysed from a regional perspective. Table 6 shows the economic and water pollution (DIN) efficiency indicators for management classes A to E in the Lower Burdekin sugarcane production system.

Table 6: Economic and water pollution (DIN) indicators for management classes A-E.

Scenario	BASE	MC A	MC B	MC C	MC D	MC E
Objective	142.77	170.10	151.51	144.44	144.30	123.90
Index	100	119	106	101	101	87
Area (Ha)	91265.63	91265.63	91265.63	91265.63	91265.63	91265.63
Index	100	100	100	100	100	100
Cane Production (1000t/yr)	9575.78	9988.42	9529.94	9520.25	9602.96	9570.83
Index	100	104	100	99	100	100
DIN Runoff (t/Yr)	1283.38	24.60	407.52	620.01	1531.76	2584.03
Index	100	2	32	48	119	201
DIN Leached (t/Yr)	2096.45	307.03	489.07	1116.68	1786.83	6389.61
Index	100	15	23	53	85	305
DIN Total (t/Yr)	3379.84	331.63	896.59	1736.69	3318.59	8973.65
Index	100	10	27	51	98	266
Fertiliser Use (t/Yr)	17428.50	7792.44	11459.19	15076.17	17467.33	26461.56
Index	100	45	66	87	100	152

As shown for the plot level (see Section 3.1), on the regional level it is also clear that changing from the base scenario to management class C provides sufficient benefits both from a financial-economic as well as a water pollutant (DIN) delivery point of view, even though cane production drops by 1% to 9520.25 Mt/yr. Management classes B and A are more cost-effective in achieving water quality targets, where class A is most cost-effective. Management classes D and E are less cost-effective in reaching water quality targets. Although class D has higher regional sugarcane growing income (1%), DIN runoff is 19% higher than in the base scenario. Class E is not cost-effective both from a financial-economic as well as a water pollutant (DIN) delivery point of view. The results shown in Table 4 are graphically represented in Figures 13 and 14.



Figure 13: Regional sugarcane growing profit from management classes A-E.

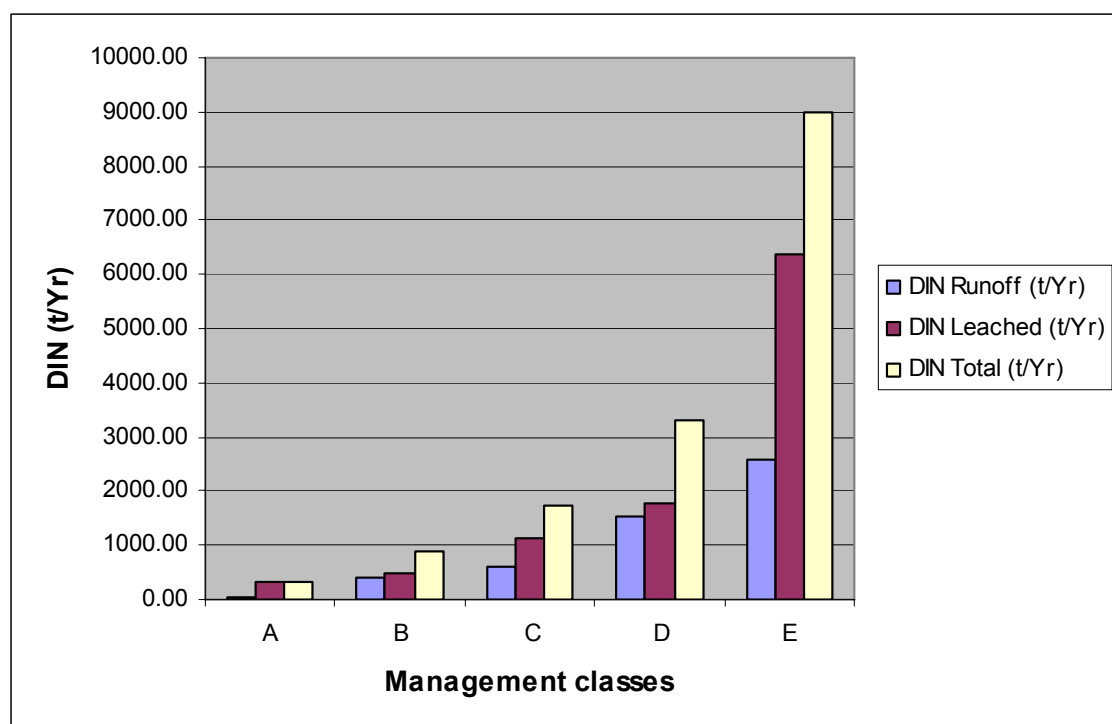


Figure 14: Regional sugarcane growing water pollutant (DIN) delivery from management classes A-E.

3.2.3 Scenario 3: Optimal distribution ('mix') of current and new MPs

In this section we look at what the optimal distribution of MPs would be based on maximising regional sugarcane growing income. First we look at the set of MPs that are currently being practiced (class B to E; see Table 1 and 4) and then the new possible best practice (class A; see Table 1, currently under experimental investigation by Thorburn *et al.* 2008) is included in the set. Table 7 provides an overview of the economic and water pollution (DIN) indicators on a regional level from these two scenarios.

Table 7: Economic and water pollution (DIN) indicators for the base scenario as well as the 'optimal mix' of current and new management practices.

Scenario	Base Scenario	Current MCs, Optimal Mix	New MCs, Optimal Mix
Objective	142.77	151.51	170.10
Index	100	106	119
Area (Ha)	91265.63	91265.63	91265.63
Index	100	100	100
Cane Production (1000t/yr)	9575.78	9529.94	9988.42
Index	100	100	104
DIN Runoff (t/Yr)	1283.38	407.52	24.60
Index	100	32	2
DIN Leached (t/Yr)	2096.45	489.07	307.03
Index	100	23	15
DIN Total (t/Yr)	3379.84	896.59	331.63
Index	100	27	10
Fertiliser Use (t/Yr)	17428.50	11459.19	7792.44
Index	100	66	45

It is clear that the current distribution of MPs produces less regional sugarcane growing income and higher DIN runoff and leaching. Average current fertiliser use is 33% (5969.31 t/yr) to 55% (9636.06 t/yr) higher comparing to the optimal mix of current and new MPs respectively. The optimal distribution of new MPs is the most (cost-) effective way to achieve water quality targets, followed by the optimal distribution of current MPs and then the current distribution of current MPs. The results shown in Table 7 are graphically represented in Figures 15 and 16.

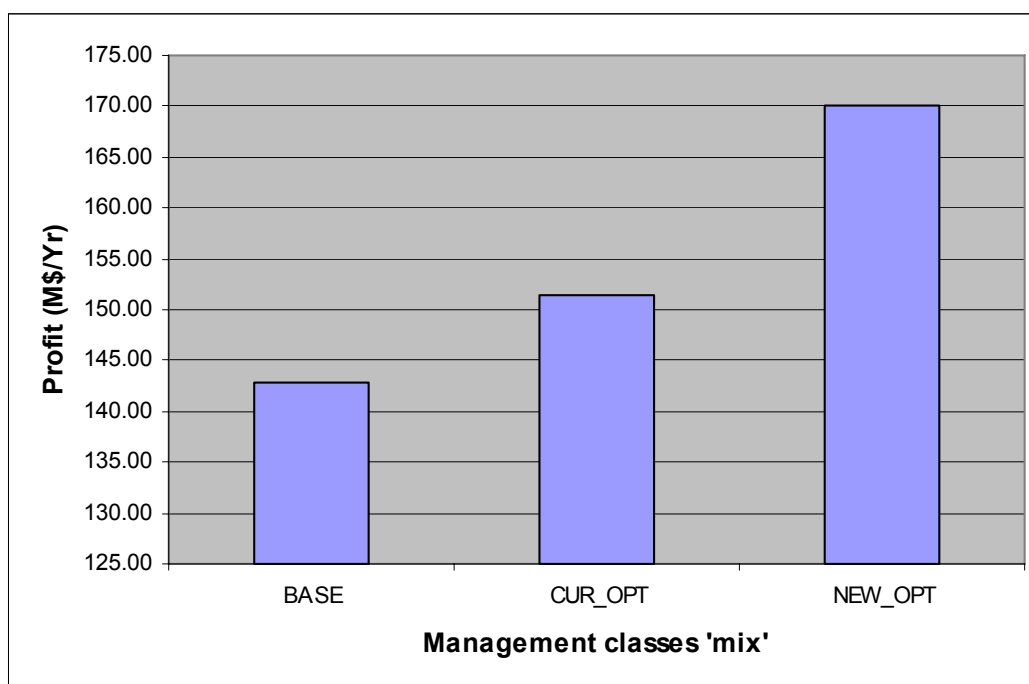


Figure 15: Regional sugarcane growing profit from the base scenario as well as the 'optimal mix' of current and new management practices.

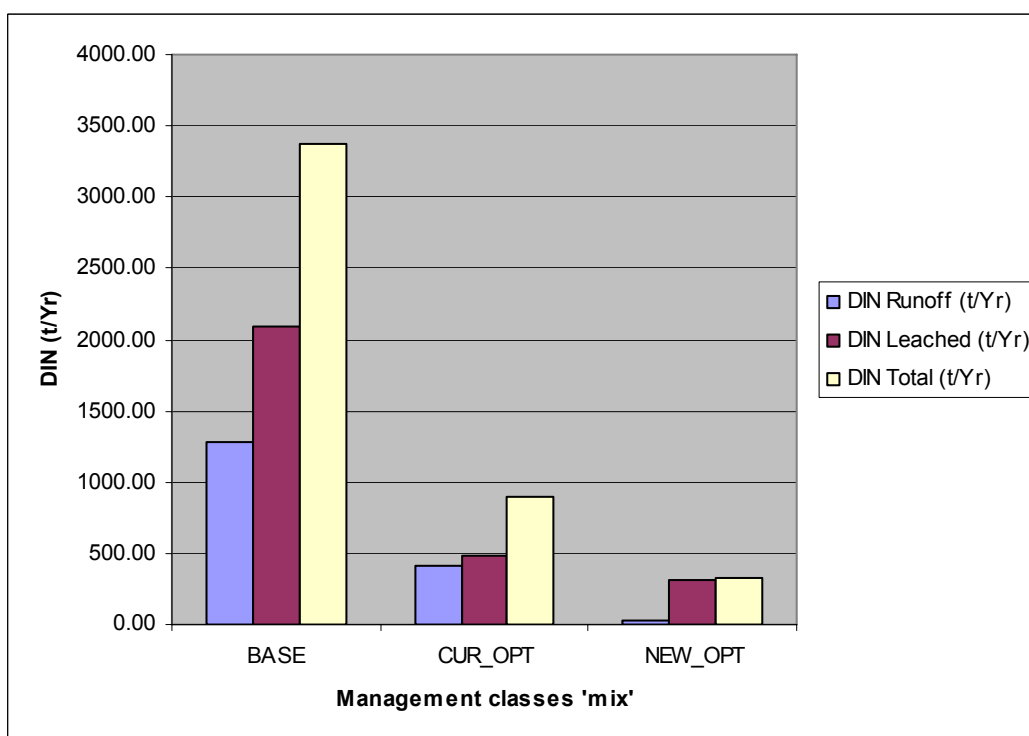


Figure 16: Regional sugarcane growing water pollutant (DIN) delivery for the base scenario as well as the 'optimal mix' of current and new management practices.

From Figures 17 and 18 on the next page it becomes clear that the optimal mix of current MPs consist only of management class B (BB-6) and the optimal mix of new MPs consists only of management class A (NBc).

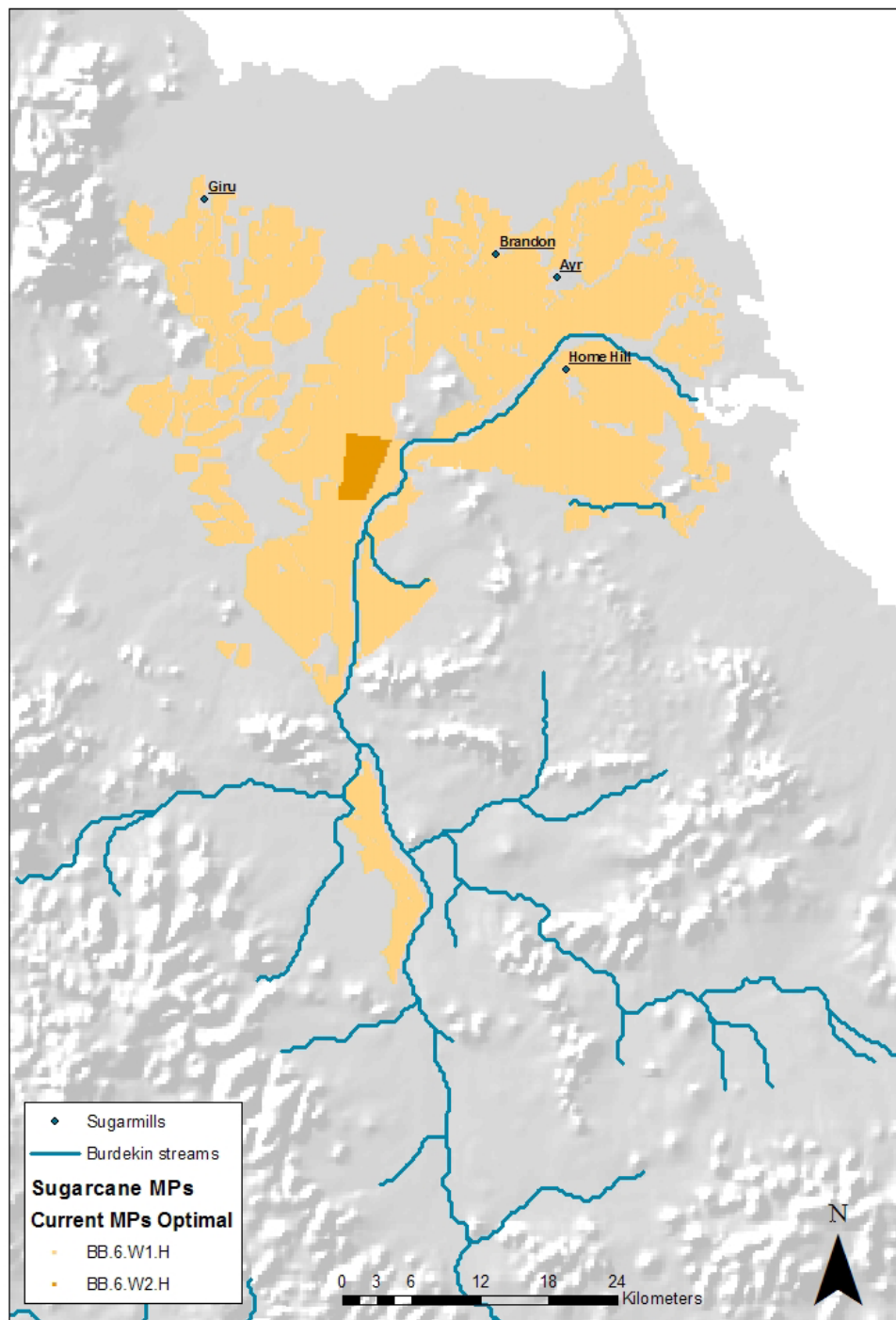


Figure 17

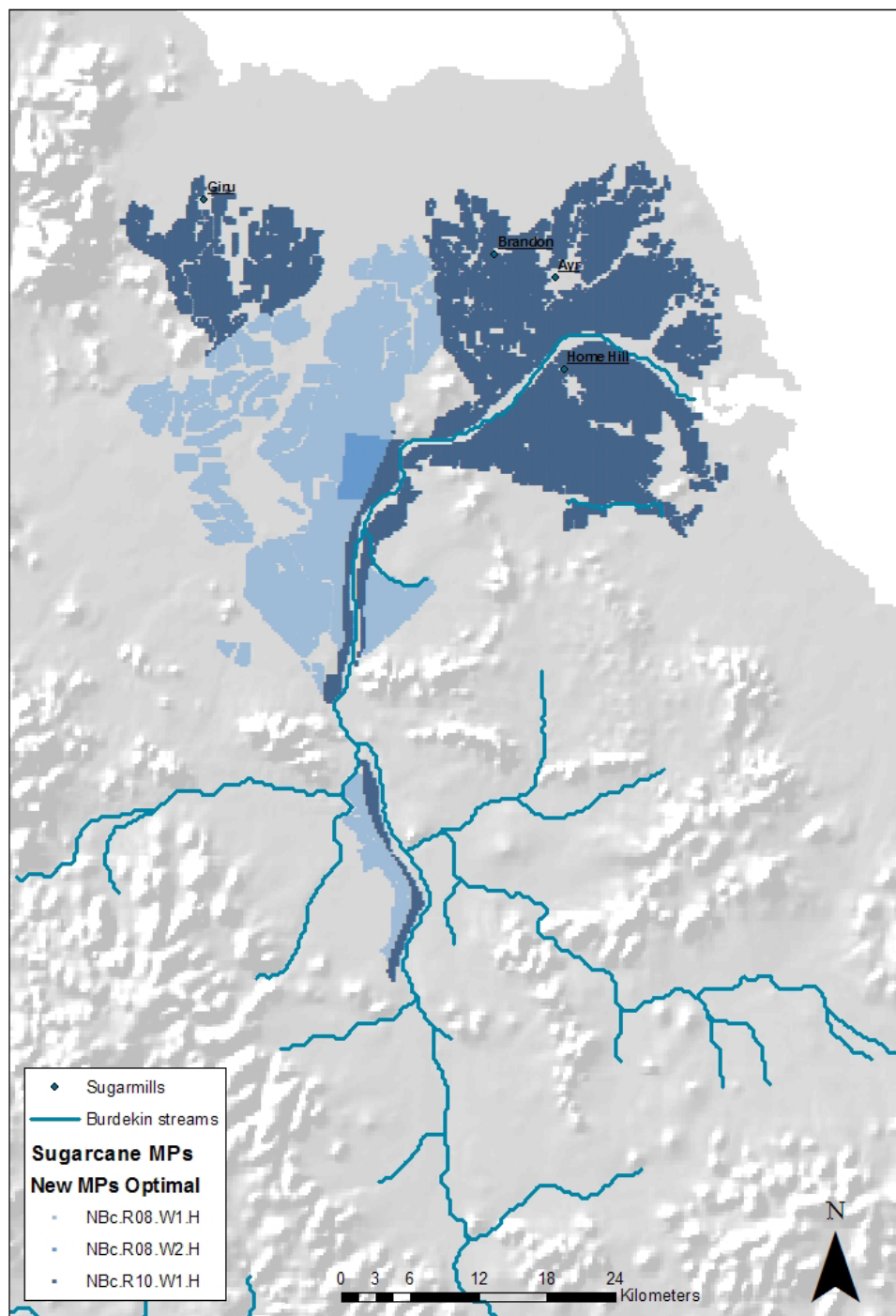


Figure 18

3.2.4 Scenario 4: Four steps to reach the optimal situation

In this section the transformation over time from the current situation to the most optimal situation given the knowledge on current and new MPs (see Section 2.1) is simulated using the EESIP model. In four steps the distribution of MPs changes from the base scenario to the optimal mix of new MPs (see Section 3.2.3). The relative change in MP distribution during the four steps is given in Table 8.

Table 8: Percentage of farmers in each fertiliser management category by area.

Step	Management Class	K	G	H
Base	E	12%	10%	10%
	D	63%	50%	50%
	C	18%	30%	30%
	B	7%	10%	10%
	A	0%	0%	0%
1	E	0%	0%	0%
	D	12%	10%	10%
	C	63%	50%	50%
	B	18%	30%	30%
	A	7%	10%	10%
2	E	0%	0%	0%
	D	0%	0%	0%
	C	12%	10%	10%
	B	63%	50%	50%
	A	25%	40%	40%
3	E	0%	0%	0%
	D	0%	0%	0%
	C	0%	0%	0%
	B	12%	10%	10%
	A	88%	90%	90%
4	E	0%	0%	0%
	D	0%	0%	0%
	C	0%	0%	0%
	B	2%	0%	0%
	A	100%	100%	100%

The economic and water pollution (DIN) indicators for the base scenario as well as the four steps to reach the optimal mix of new management practices are presented in Table 9.

Table 9: Economic and water pollution (DIN) indicators for the base scenario as well as the four steps to reach the 'optimal mix' of new management practices.

Scenario	BASE	Step 1	Step 2	Step 3	Step 4
Objective	142.77	148.26	156.40	168.09	170.10
Index	100	104	110	117	119
Area (Ha)	91265.63	91265.63	91265.63	91265.63	91265.63
Index	100	100	100	100	100
Cane Production (1000t/yr)	9575.78	9568.43	9660.65	9935.77	9988.42
Index	100	100	101	104	104
DIN Runoff (t/Yr)	1283.38	591.80	283.58	63.92	24.60
Index	100	46	22	5	2
DIN Leached (t/Yr)	2096.45	1002.44	511.15	328.30	307.03
Index	100	48	24	16	15
DIN Total (t/Yr)	3379.84	1594.23	794.73	392.22	331.63
Index	100	47	24	12	10
Fertiliser Use (t/Yr)	17428.50	13857.67	10685.30	8198.50	7792.44
Index	100	80	61	47	45

It is clear that each step leads to improved water quality (DIN) and increased regional sugarcane-growing profits (9% or 27.33M\$/yr). The biggest results are achieved in the reduction of DIN runoff with 98% (from 1283.38 t/yr to 24.60 t/yr) and total fertiliser use is decreased with 55% (from 17428.50 t/yr to 7792.44 t/yr). The results shown in Table 9 are graphically represented in Figures 19 and 20.

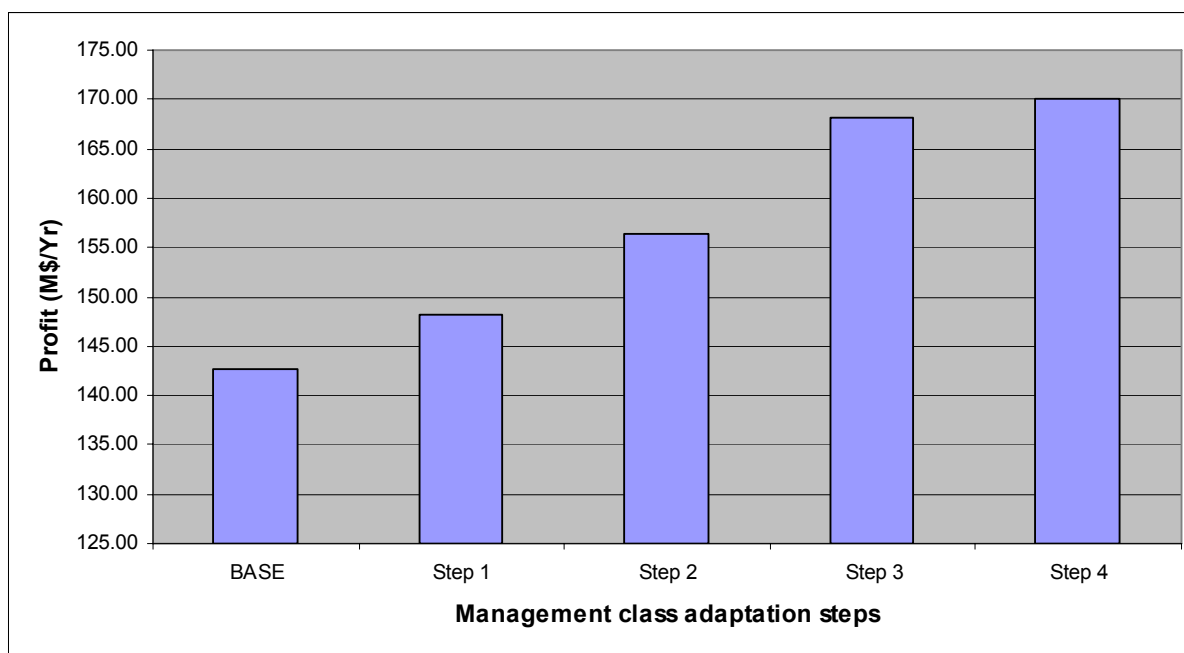


Figure 19: Regional sugarcane growing profit from the base scenario as well as the four steps to reach the 'optimal mix' of new management practices.

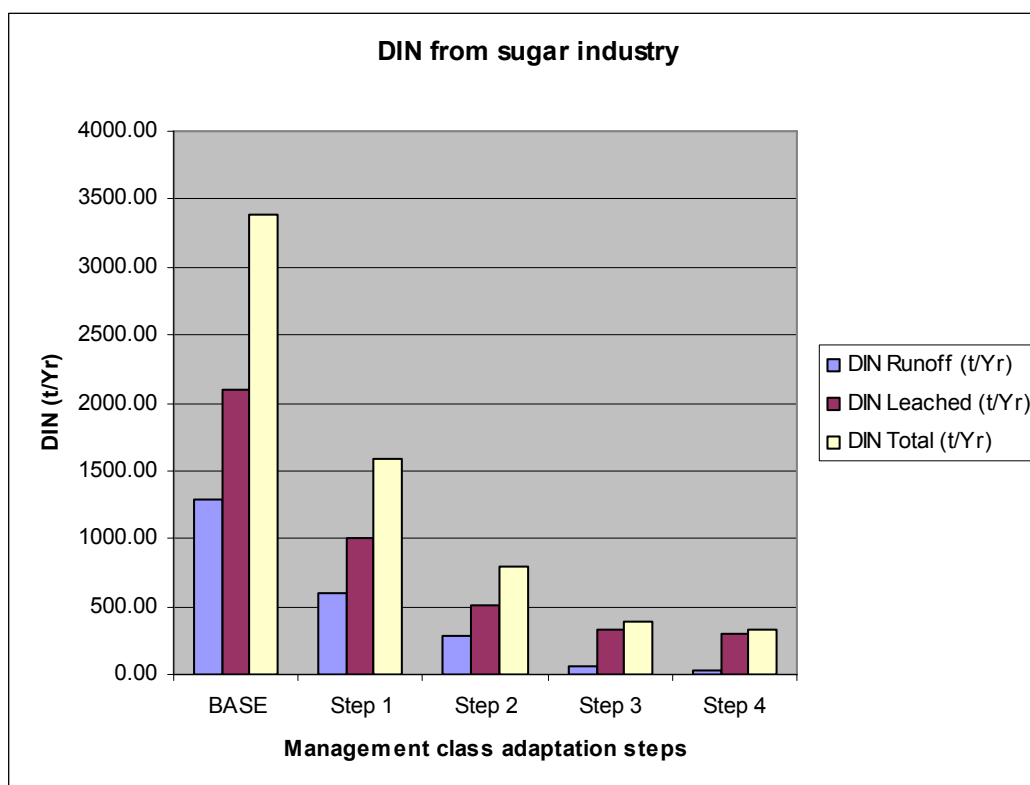


Figure 20: Regional sugarcane growing water pollutant (DIN) delivery for the base scenario as well as the four steps to reach the 'optimal mix' of new management practices.

Figures 21 to 24 on the next pages show the spatial change in relative distribution of the MPs. It is apparent that the MPs with the highest yields are practiced nearest to the mill due to increasing transport costs (\$/kg/km), based on the Von Thünen (1826) model of farm price, land use and land rent.

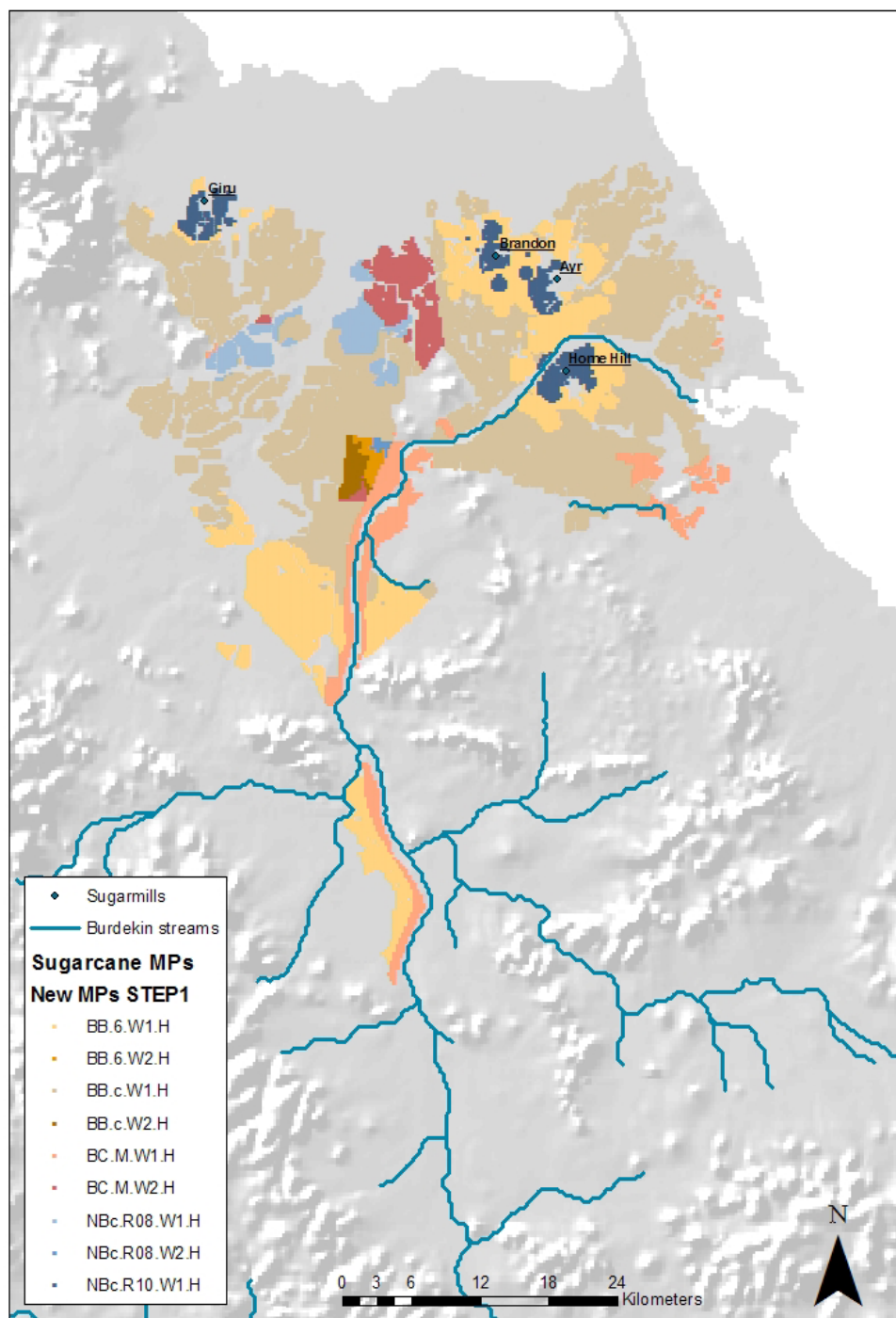


Figure 21

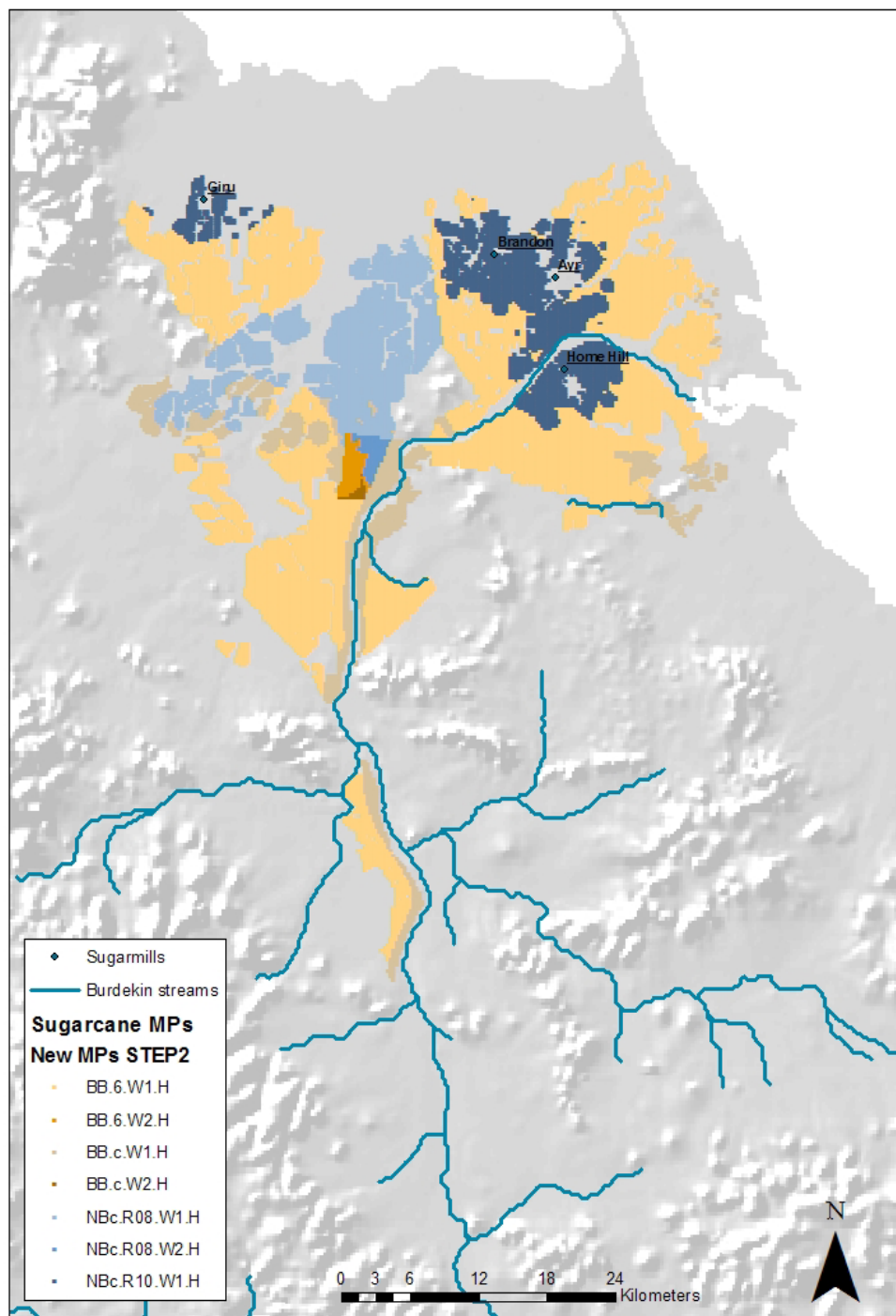


Figure 22

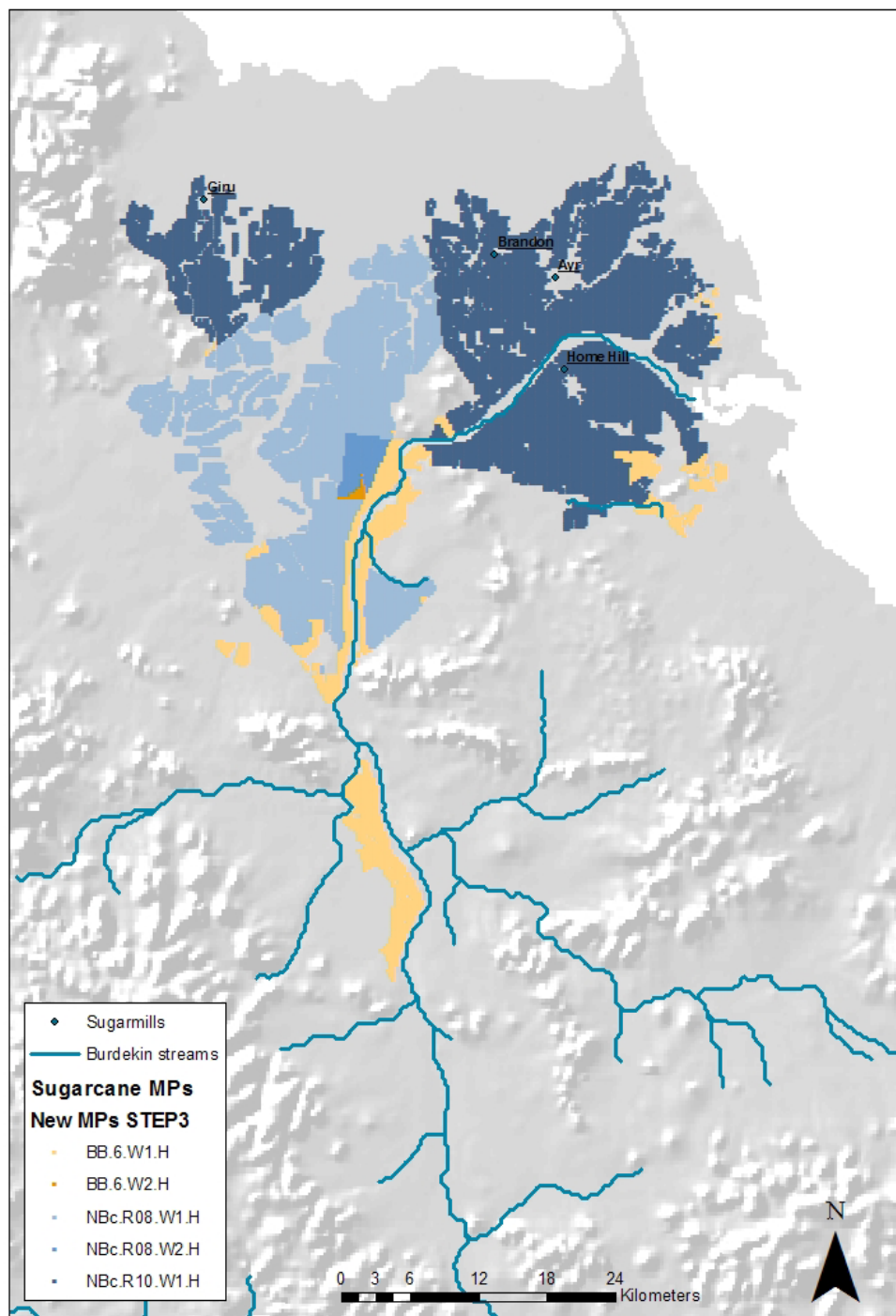


Figure 23

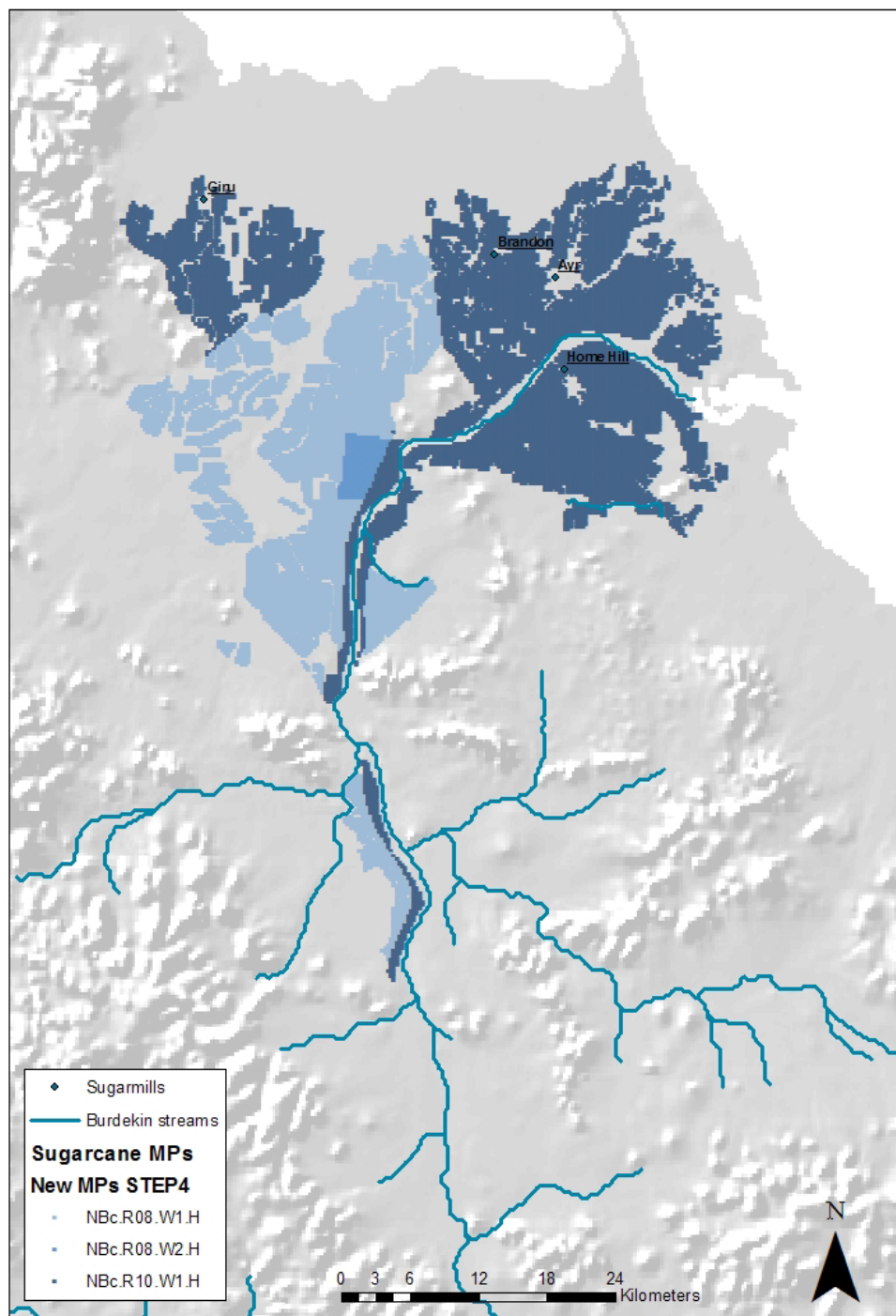


Figure 24

Conclusion and discussion

In this report we apply and extend the approach developed by Roebeling *et al.* (2005), to the analysis of the **plot level** (cost-)effectiveness of best management practices (BMPs) for water quality improvement in sugarcane production. The approach is based on linkage of the specialized production system simulation model APSIM (see eg. Keating *et al.* 1999) and the water quality model SedNet/ANNEX (see Bartley *et al.* 2004), in combination with sound cost-benefit analysis (Zerbe and Dively, 1994). Based on literature data, field observations and expert knowledge, this approach allows us to assess the (cost-) effectiveness of current and future BMPs for water quality improvement (dissolved inorganic nitrogen) in the Lower Burdekin catchment. To determine the (cost-) effectiveness of BMPs for water quality improvement in sugarcane production on a **regional level** the Environmental Economic Spatial Investment Prioritization (EESIP) model (based on Roebeling *et al.* 2006) is applied.

Table 2 (see Section 3.1) summarises the (cost-)effectiveness of BMPs in sugarcane production in the Lower Burdekin. Analysed BMPs in sugarcane production include tillage management, fallow management and nitrogen application rate. Results show that it is attractive from a financial-economic perspective as well as a water pollutant (DIN) delivery perspective to change tillage management (move towards zero tillage systems) and fallow management (i.e. move from a bare to a legume fallow). Furthermore, matching nitrogen application rates to crop requirements is attractive from a financial-economic as well as a water pollutant (DIN) delivery perspective.

It is shown that in the Lower Burdekin the introduction of BMPs result in financial gains due to increased yields, decreased fertiliser application and lower operational costs. From the regional analysis, results show that the introduction of the new management class A could lead to a regional profit gain of 9% (27.33 M\$/yr). Furthermore, this management class A could lead to a reduction of DIN runoff of 98% (from 1283.38 t/yr to 24.60 t/yr) while regional fertiliser use can be decreased with 55% (from 17428.50 t/yr to 7792.44 t/yr).

A number of caveats to this study must be mentioned. First, this BMP cost-effectiveness assessment does not include costs associated with BMP implementation (transaction costs) at the farm and community level. Second, more information, especially on N lost in runoff, is needed to evaluate and develop future N management recommendations to reduce environmental impacts of sugarcane production in the region (Thorburn *et al.* 2008). Third, in this study we assume 100% DIN delivery to the river mouth from plot level runoff and 17% from deep drainage leaching. Further research is recommended to clearly state the relationship between DIN available for runoff and for deep drainage leaching and net delivery to the coast in the Lower Burdekin. Fourth, it must be noted that the figures in this document are generated for the Lower Burdekin area and, consequently, care should be taken when transferring these figures to other catchments since yield, input cost and gross margin figures are dependent on locally specific biophysical and socio-economic conditions and water pollutant delivery figures are dependent on locally specific biophysical conditions and land use patterns. Finally, care should be taken when using the figures presented in this study for policy and planning purposes since the presented results provide an indication of change rather than absolute quantifications of BMP effects.

Acknowledgements

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Framework description for a spatially explicit model that allows for the assessment of sustainable land use and land management patterns in GBR catchments – with Project 2.5i.4

The project vision is an integrated model that links reef and industry outcomes under IPCC climate change futures to implementation of BMPs in the catchment. This vision is structured over four primary system components; agriculture, water quality, reef condition and industry income. **Appendix 1** describes the framework developed for a spatial model that assesses the impacts of climate change on the water quality outcomes for best management practice (BMP) implementation in land based management systems.

The terrestrial based environmental-economic model EESIP that will be used for this framework has been developed (see Roebeling, 2006). An application of the approach is provided for the Tully-Murray catchment. For further detail on the approach as well as its application, please refer to Roebeling *et al.* (2007). For detail on the methodology and results concerning scenarios for water quality improvement via DIN reduction through the implementation of BMPs in the Tully Murray catchment please refer to Roebeling *et al.* (2007).

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Project 3.7.5 Project Progress Overview

The reporting on the Burdekin grazing industry has been delayed and will be delivered as soon as possible.

Grazing BMPs have been identified and grazing production system simulation using GRASP need to be run. The cost components of the different MPs are being identified and valued. As soon as all the information has been gathered the same approach to assess BMP (cost-) effectiveness will be used as has been for sugarcane in this report.

Due to the change in project leadership the ending of 2007, this activity will not be reported on in the current milestone reporting period and is scheduled as an out year activity.

Implementation costs of current and future land use and management options for water quality improvement will be assessed via reference site (from Thorburn *et al.* 2008) (cost-) survey analyses.

Communication, major activities and/or events

- Burdekin Dry Tropics case study: Several meetings with I. Dight (CCI-Burdekin program leader), I. Gordon (CSIRO – MTSRF Program 7 Leader) and P. Thorburn (CSIRO – Burdekin SRDC project leader), to align MTSRF Project 3.7.5 activities with on-going programs, projects and activities in the Upper and Lower Burdekin catchment. All collaborations are highly supported and endorsed by all parties.
- MTSRF Water Quality Operations Committee meeting (30/10/2007): Member of the Water Quality Operations Committee (WQOC) for MTSRF, thus providing constructive input to issues considered at WQOC meetings and liaising with stakeholders on matters relating to the WQOC.
- MTSRF Projects 2.5i.4 and 3.7.5 coordination meeting (January 2008): The meeting objective was to conceptualise the spatial linkage model that integrates land use and management, water pollution and reef impact in a spatially explicit way while taking into account uncertainty. Workshop participants include I. Gordon (CSIRO – program leader MTSRF Program 7), S. Wooldridge (AIMS – MTSRF Project Leader 2.5i.4), R. Miles (CQU), P. Marshall (GBRMPA), J. Maynard (GBRMPA), I. van der Putten (GBRMPA) and C. Thomas (MU).
- Liaison with Burdekin NRM group via Dr Peter Thorburn to obtain Sugarcane Management Practice information.
- During milestone reporting period.
- Monthly MTSRF Project 3.7.5 meetings (planning, progress and review).
- RRRC Conference (30/04/2008): Project 3.7.5 presentation to major players in catchment-to-reef research arena.
- Sixth meeting of the MTSRF Water Quality Operations Committee (28 May 2008).
- During next milestone reporting period.
- Monthly MTSRF Project 3.7.5 project meetings.
- MTSRF Projects 2.5i.4, 3.7.5, 4.9.6 and 4.9.7 coordination meetings.
- MTSRF Water Quality Operations Committee meetings.
- Reef Water Quality Partnership (RWQP) meetings.

Appendix 1 – Milestone 4: Tools to support resilience-based management in the face of climate change (Project 2.5i.4)

Iain Gordon and Colette Thomas, 7 June 2008

Project Leader: Scott Wooldridge, AIMS

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Objective

To describe the framework developed for a spatial model that assesses the impacts of climate change on the water quality outcomes for best management practice (BMP) implementation in land based management systems.

Outcome

The project vision is an integrated model that links reef and industry outcomes under IPCC climate change futures to implementation of BMPs in the catchment. This vision is structured over four primary system components; agriculture, water quality, reef condition and industry income. The links between these components provides the backbone to the integrative framework shown in Figure 1.

The framework shows where explicit links between system components will be modelled, indicating areas of greater uncertainty and potential feedbacks. Feedbacks will not be explicitly represented in the proof-of-concept models but are indicated in the framework for clarity and completeness.

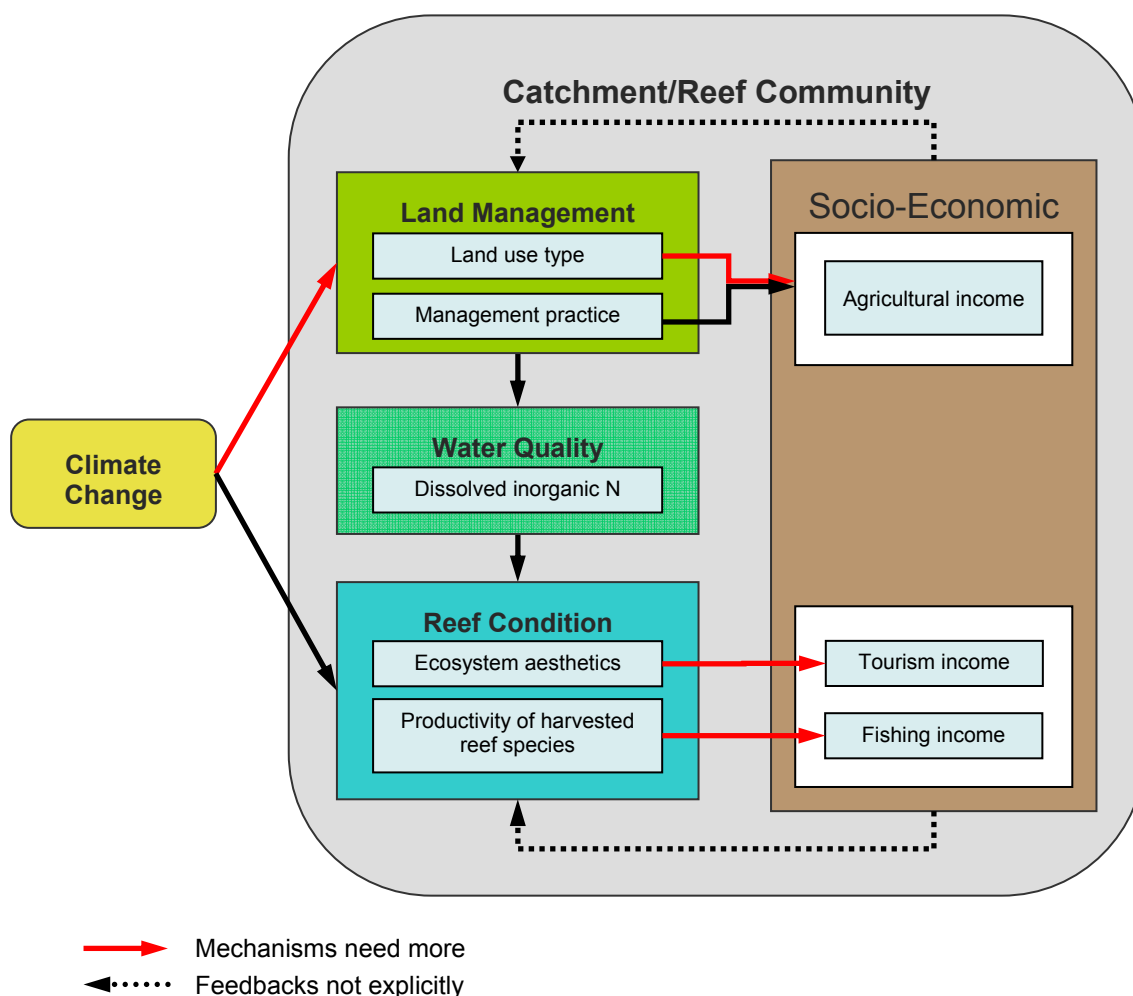


Figure 1: The whole-of-system integrative framework for coastal catchments in the Great Barrier Reef region.

Integrative Framework

Land use management components of the Tully catchment are modelled as BMPs, which are land use specific. Given the focus on the dissolved inorganic nitrogen (DIN) component of water quality, fertiliser BMPs for sugarcane provide the focal input for the proof-of-concept model (under development) that this framework describes. Additional land use/land practice pairings can be investigated in later phases if appropriate.

Implementation of fertiliser (N) BMPs incurs costs to landholders and land managers, but can create efficiencies in productivity, minimise fertiliser supply costs and reduce off-farm nutrient loss. These positive types of outcome translate directly to farm profits and water quality improvements. In the proof-of-concept model, these relationships will be summarised using the Environmental Economic and Spatial Investment Prioritisation (EESIP) model, in which the optimal distribution of BMPs to achieve maximum profit (or minimum cost) and minimum nutrient loss (i.e. DIN supply to the river) are calculated. Industry-specific production simulation models produce estimates of land use productivity given a specific land management practice. The Agricultural Productivity Simulation (APSIM) model for sugarcane will be used as the case study. Production model results will be used by EESIP to determine the cost-benefit tradeoffs for agricultural income. Results from the SedNet/ANNEX

hydrological model (Sediment River Network /Annual Network Nutrient Export) are used by EESIP to determine DIN supply to the river mouth under the land practice(s) of interest.

These outcomes are used in the framework to link the land use management component with the socio-economic and water quality components of the system. The relationship between land practice and DIN supply has been developed to a point sufficient for immediate inclusion in the model framework. Climate change could change also agricultural productivity. Changes in productivity could lead to different 'optimal' distributions of management practices, and these could have consequences for agricultural income and DIN supply to the river. However relationships between climate change and land practice (red arrow in Figure 1) require further development. In future work these linkages could be modelled by accounting for climate change effects on productivity under different land practices (using various production system models, e.g. APSIM for sugarcane), and then using those results in the EESIP model to determine the flow-on effects to income and DIN supply to the river mouth.

Rivers are a nutrient conduit to coastal waters and ecosystems, and nutrients including DIN can affect coral reef health. In this project the pathway used to demonstrate that relationship focuses on the role that DIN plays in exacerbating climate change-induced coral bleaching and mortality. Bleaching events, especially under elevated DIN conditions, can affect reef aesthetics, which may in turn impact the profitability of the tourism industry. In addition to aesthetic consequences, the ability of coral reefs to support commercial and recreational fishing industries may also be altered by bleaching events.

Water quality outcomes are used in the framework to link reef condition with socio-economic components. The current state of knowledge for the relationship between water quality and bleaching is strong, however understanding of the relationships for example between bleaching and fishery income, and bleaching and tourism income, is in its infancy.

Feedback pathways may exist at different spatial and temporal resolutions within the modelled system. These pathways could conceivably link each compartment in the framework to each other. For simplicity, only the pathways connecting socio-economic conditions with land use management and reef condition are emphasised in the framework (Figure 1). The socio-economic ↔ land use management pathway may for example, include processes whereby current land management choices influence e.g. productivity-driven income, land values, quality of education etc. (socio-economic conditions), which affect future land management activities such as land use change. The socio-economic ↔ Reef condition pathway may for example, include processes whereby current Reef aesthetics and productivity levels influence the quality or quantity of consumer demand (socio-economic conditions), which affects future Reef condition.

These feedbacks can be important to system functionality and may alter the way cost and ecological tradeoffs are evaluated. Given sufficient resourcing, these feedback relationships could be examined in later project phases, after the utility and acceptability of the basic framework has been completed and evaluated.

Next Steps

The CSIRO team has committed to completing two further milestones which extend and improve the current model:

- Assess ecological and economic costs/benefits of implementation of land management practice changes in the Tully catchment for reef health outcomes (January 2009); and

- Scope the feasibility and utility of developing a model framework to assess the impacts of climate change effects on land practice changes on the delivery of DIN from the Tully into the GBRWHA (June 2009).