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Review of socio-economic constraints to and incentives for the adoption of land use and management options for water quality improvement in the Tully-Murray catchment (Wet Tropics)

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EXECUTIVE SUMMARY

This report provides an economic assessment of instruments promoting adoption of land management practices (MPs) by landholders for the Wet Tropics. Individual management practices are represented in *suites* of practices according to the ABCD framework in use by NRM regions for Reef Rescue Transitional Funding. The ABCD framework provides a standard definition of MPs and a four step scale (D-C-B-A) of improvement from "old" to "cutting edge" MPs.

More specifically, the objectives of this study are to:

- determine the private-economic consequences of MP adoption;
- determine the effectiveness of MPs adoption in reducing nutrient supply;
- assess the effectiveness of taxes and subsidies to promote the adoption of MPs.

We therefore apply an approach that combines a financial analysis of MPs in sugarcane, beef cattle production, banana cultivation and production forestry at the paddock scale and a farm household modelling approach for various types of producers at the farm scale. Adoption rates are assessed by predicting how different types of farmers, or farming agents, will respond to different policy interventions. The typology of farmers in the study area was developed via qualitative interviews with the widest possible range of farmers and land managers. The approach allows us to estimate regional socio-economic and environmental consequences of implementing a specific policy, such as changes in local income, employment and nitrogen run-off. Policy scenarios include: 1) regulations on water quality improvement via specified end of river DIN delivery reductions and fertiliser input restrictions; 2) subsidies for reducing fertiliser input and; 3) taxes on fertiliser use. Furthermore, we simulate the situation where all farm types would manage their crops via the preferred code of practice, or MP-A.

When comparing subsidy and tax levels on the basis of cost-effectiveness, we find that the fertiliser restriction subsidy provides the most cost effective incentive for reducing DIN delivery, followed by the fertiliser use tax. Besides the positive response on water quality, the policy instruments fertiliser tax and fertiliser restriction subsidy, facilitate a change towards MP-A and MP-B, however, since fertiliser is not a big contributor to the production of beef and timber, these industries will not be impacted to the extent that the sugarcane and banana growing industries are. When comparing the 'regulatory' scenarios, we can see that the reduction of 80% DIN delivery, as recommended by the Tully WQIP, will come at significant private costs and a long term drop in sugarcane production which can jeopardize the viability of the mill and the livelihood of the sugar industry with large social consequences to the region.

We show that while financial motives are important in explaining adoption of management practices, there are a wide range of other non-financial factors explaining the current non-adoption of management practices by a significant number of farmers.

A number of caveats of this study must be mentioned. Production system simulation data should be re-evaluated and updated. In general, more attention should be paid to uncertainty in the modelling and the provision of risk associated with specific practices. Furthermore, it could be expected that small farmers face higher costs per hectare (economies of scale principle) or produce less per hectare and therefore our knowledge on the implications of enterprise heterogeneity needs to be increased. The exact causes why farmers resist change needs to be investigated and quantified more deeply, for instance via the monitoring of the exact costs of change (training, machinery and other capital requirements, land conversion etc.) and by gathering better information on the exact risk aversion of farmers via socio-economic surveying. Labour constraints in the model restrict employing units such that

they cannot make any change that would require more labour - a potentially significant constraint for larger enterprises. Finally, the costs of enforcing and monitoring regulations are not included in the analyses which could have implications on cost-effectiveness, especially on the adoption and delivery process.

1. INTRODUCTION

In this report an approach will be presented that explores which policy instruments are likely to be most effective in stimulating adoption of prioritized land management practice (MP) changes. For example, policy makers can assess how fertilizer taxation will facilitate the adoption of improved management practices by specific cane growers in the Tully-Murray basin. Adoption rates are estimated by predicting how different types of farmers are likely to respond to different policy interventions. Furthermore, the corresponding farm level socio-economic and environmental consequences of implementing the policy are modelled, such as changes in income (via economic surplus), employment and nitrogen run-off.

The approach is based on the integration of a financial-economic analysis of actual and aspirational MPs in sugarcane, beef cattle production, banana cultivation and production forestry at the plot level (from Roebeling et al., 2004), and a private economic farm household modelling approach for agricultural producers at the farm level (see for example Singh et al., 1986; Sadoulet and DeJanvry, 1995; Roebeling et al., 2000). By linking farm profiles to income and productivity, this approach allows quantitative determination of the instruments most likely to achieve the most cost-effective distribution of MP change. Furthermore, this private-economic analysis provides insights about the likelihood of adoption of 'Best' MPs (BMPs) by agricultural producers and subsequent private-economic and water quality effects.

2. METHODOLOGY

2.1. Farmer profile

To develop a profile or typology of farmers, i.e. farming agents, in the Tully basin, qualitative interviews with the widest possible range of farmers and land managers were carried out in the Tully basin in 2006. These interviews served a number of projects including: (i) 'Future visions for the Tully-Murray floodplain', funded by CSIRO's Water for a Healthy Country Flagship and Sustainable Ecosystems Division, (ii) 'Community uses and values of waters in the Tully-Murray catchment', funded by terrain NRM Ltd and CSIRO's Water for a Healthy Country Flagship and Sustainable Ecosystems Division, (iii) this current project 3.7.5 'Socioeconomic constraints to and incentives for the adoption of land use and management options for water quality improvement', funded by MTSRF and CSIRO Sustainable Ecosystems. While interviews have also been carried out with community members including Traditional Owners, other Indigenous people, local (non-farming) residents, councillors, tourism operators, conservationists, and concerned locals, the focus for MTSRF 3.7.5 project is 'farming activities and management approaches' in the Tully basin.

Described below are key findings from the profile analysis to facilitate the economic modelling of agents in the study area.

2.1.1. Likelihood to adapt to MPs

Based on the farmer profiling done by Dr Iris Bohnet and on personal conversations with Dr Iris Bohnet and Mr Tony Webster from CSIRO, the following results represent farmers' likelihoods to adapt to MPs or management practice 'suites' in the Tully-Murray catchment.

Table 1 classifies farmers and their suggested ability and or willingness to change. We define change as converting to a MP that is improving water quality.

Table 1: Farmers profiles (typology) and ability and or willingness to change

Profile	Farm type	Change	Description
Large sugarcane farmers	1	++	The large sugarcane farmers are willing to adapt to improved MPs in the case where it will provide them with financial benefits (win-win) as well. They have a knowledge seeking attitude. From an economic point of view, their behaviour could be described as profit maximising. In response to policy interventions, farmers with this profile would have a positive attitude towards incentive schemes such as pollution control subsidies, even if this would mean 'sharing the burden'. Large sugarcane farmers look closely at how the business operates and therefore know what their costs are; often on a per tonne basis (e.g. they know their fertiliser costs per tonne and what proportion it makes up of the total cost per tonne). Large sugarcane farmers are business operators driven by income maximization via cost minimisation.
Medium sugarcane farmers	2	+	The medium sugarcane farmers have a more sceptical view of MPs. Of all sugarcane farmer profiles, the medium sugarcane farmers seem to experience the biggest trade-off between labour

			and leisure time, where sacrificing leisure time to labour for changing MPs can be seen as a constraint. Medium sugarcane farmers are traditionalists, being a sugarcane farmer drives them. Their biggest source of information is other cane farmers.
Small sugarcane farmers	3	-	This profile represents farmers with multiple restrictions, such as on capital investments and labour (these farmers work off-farm so in order to invest time into changing practice; they need to hire labour, which comes at a substantial cost). In the past, this profile was likely to sell their land to forestry companies or other sugarcane farmers if restrictions were too binding. Small sugarcane farmers' successors may not take over the business from their parents. Therefore, it is possible that some of these farms will be sold in the future. Because the small sugarcane farmers work mainly off-farm, exposure to extension material or time to learn about better farming techniques is limited.
Mixed crop farmers	4	++/+	The farmers in this profile use diversification to increase flexibility towards market fluctuations and other risks. Often different members of the family supervise a different cropping system and since every family member works on-farm, labour is hardly seen as a constraint. It must be noted that leisure time is valued so some restriction to labour intensive MPs must be incorporated. The mixed farmers are considered to be willing to change in case of win-win situations. Furthermore, improved water quality could lead to 'green labelling' and improve the public opinion towards their business. Growing bananas require high level precision farming, and this translates to sugarcane farming. These farmers will actively look for information but are able to critically evaluate it and decide if new ideas will work. Being a good farmer is their driver.
Graziers	5	-	The graziers are seen as very independent traditionalists. Their biggest source of information is other farmers. Being a grazier drives them.

2.1.2. Farm type geographical information

Table 2 provides information on the different types of farms. This data is based on geographical information layers on land use, soil type and farm boundaries. Table 2 shows the soil type (S1, S2, S3 and S4) distribution per agricultural industry. S1 refers to a soil type where plant growth is not limited by moisture deficit and water logging stress; S2 refers to a soil type where plant growth is limited by moisture deficit stress; S3 refers to a soil type

where plant growth is limited by water logging stress; and S4 refers to a soil type where plant growth is limited by both moisture deficit and water logging stress.

Table 2: Soil type distribution per agricultural industry

	Sugar area with soil type (%)				Banana area with soil type (%)			
Farm type	**S1**	**S2**	**S3**	**S4**	**S1**	**S2**	**S3**	**S4**
1	0%	56%	2%	42%	0%	0%	0%	0%
2	13%	43%	1%	42%	0%	0%	0%	0%
3	18%	33%	3%	48%	0%	0%	0%	0%
4	14%	11%	2%	14%	5%	1%	1%	6%
5	0%	0%	0%	0%	0%	0%	0%	0%
Farm type	**Cattle fattening area with soil type (%)**				**Timber area with soil type (%)**			
1	**S1**	**S2**	**S3**	**S4**	**S1**	**S2**	**S3**	**S4**
2	0%	0%	0%	0%	0%	0%	0%	0%
3	0%	0%	0%	0%	0%	0%	0%	0%
4	0%	0%	0%	0%	0%	0%	0%	0%
5	10%	7%	2%	5%	12%	2%	2%	7%
	48%	23%	8%	21%	0%	0%	0%	0%

2.1.3. Labour pool

Based on the farmer profiling done by Dr Iris Bohnet and on personal conversations with Dr Iris Bohnet, the following results represent labour pool (availability) in the Tully Murray catchment (based on the average farm sizes used in the profiling clusters).

Table 3: Labour availability in FTEs for the different types of farmers

Profile	On-farm labour (fte)	Hired labour (fte)	Off-farm labour (fte)
Large sugarcane farmers	3	1	1
Medium sugarcane farmers	1	0.1	0.5
Small sugarcane farmers	0.2	0.05	1
Mixed crop farmers	4	4	0
Graziers	0.5	0	1.5

2.2. Management practice framework

The MP framework used was adopted from the 'ABCD' framework of MP classification in use by NRM regions for Reef Rescue Transitional Funding. The ABCD framework was originally adapted by Reef Catchments NRM (formerly Mackay-Whitsunday NRM) to sugarcane from the Queensland Department of Primary Industries grazing land assessment tool. Since publication of the framework other NRM regions (including Terrain NRM) have joined together with Reef Catchments to adopt the framework and standardise MPs into a state wide framework adopted by all of the regions, and it has been extended to cover land uses other than sugarcane. The framework is a planning tool and is determined by criteria relating to:

- The resource condition achieved by adopting the MP in the short, medium and long term;
- The acceptability of the MP to the community; and

- The feasibility of achieving wide adoption of the MP in the short, medium and long term.

The ABCD framework provides a standard definition of MPs and a four step scale (D-C-B-A) of improvement from “old” to “cutting edge” MPs. Each step of the framework is defined in Table 6.

Table 4: State wide ABCD framework definitions

Class	Category	Description of practice	Effect on resource condition	Effect on profitability
A	Aspirational / cutting edge	Practice extends BMPs, providing society with additional ecosystem services	When validated, practice likely to achieve long term resource condition goals if widely adopted	When validated, improves profitability in the medium to long term (may reduce profitability during the transition)
B	Best practice	Practice meets agreed industry and community BMPs	Practice likely to achieve medium term resource condition goals if widely adopted	Improves profitability in the short to medium term
C	Compliant	Practice meets minimum industry and community standard and regulatory obligations. Meets legislative requirement, code of practice or locally agreed duty of care	Practice unlikely to achieve acceptable resource condition goals if widely adopted	Decline of profitability in the medium to long term
D	Degrading / old	Practice unacceptable by industry and community standards	Practice likely to degrade resource condition if widely adopted	Decline of profitability in the short to medium term

In the framework, the class A, B, C or D represents a *suite* of individual management practices. Having a suite of practices for each class allows the modelling framework to define each suite and run simulations for these management practices. Model simulations were run for each class in the sugarcane, grazing, forestry and banana land uses. The MPs for each land use (except forestry) that were classified into each class are listed in Tables 7 to 9.

Table 5: Sugarcane management practices for the ABCD framework used in modelling

	Class			
Practice	**A**	**B**	**C**	**D**
Tillage	Zero	Minimum	Conventional	Conventional
Fallow	Legume	Legume	Bare	Bare
Fertiliser	N replacement*	Six Easy Steps**	150 kg N/ha	210 kg N/ha
Plant N application	0%	0%	75%	75%

* N replacement sets the nitrogen application rate applied 1 kg N/ha for every tonne of cane that was harvested in the previous year. This is used to simulate spatial application of nitrogen.
** The Six Easy Steps practice determines the nitrogen application rate based on soil type. In the modelling S1 = 150kg/ha, S2 = 150kg/ha, S3 = 120kg/ha and S4 = 150kg/ha.

Table 6: Banana management practices for the ABCD framework used in modelling

	Class			
Practice	**A**	**B**	**C**	**D**
Fertiliser applied to achieve maximum yield	100%	100%	150%	200%

Table 7: Grazing management practices for the ABCD framework used in modelling

	Class			
Practice	**A**	**B**	**C**	**D**
Stocking rate (Animal Units per hectare)	2.0	2.5	3.0	3.5

2.3. Production system simulation

For the analyses of adoption of MPs, production system simulation data was used that was reported on in year 1 of this project (see Roebeling et al., 2007). From the matrix of MPs that was created for that report, the combination (suite) of practices and corresponding agronomic data was selected to match the criteria as described in the previous paragraph.

2.4. Cost-benefit analyses

Cost benefit data was used that was reported on in year 1 of this project (see Roebeling et al., 2007) to analyse the adoption of MPs. For more information on the methodology used for the cost benefit analysis, please refer to Roebeling et al., (2007). Below is the summary of the selection of MPs suites regarding plot level financial economics for sugarcane cultivation, grazing, banana cultivation and production forestry.

Figure 1: Sugarcane growing gross margins for different MPs on different soil types

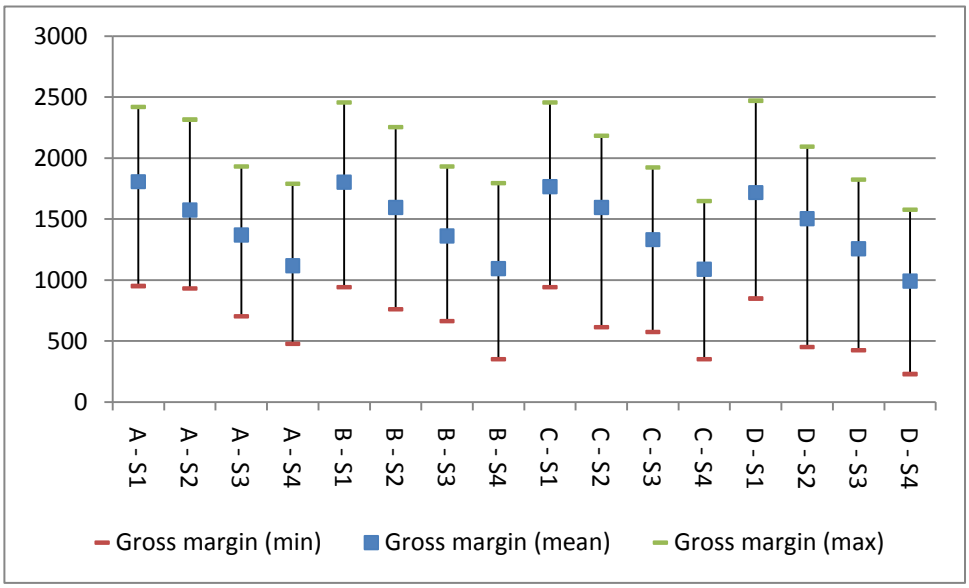


Figure 2: Grazing gross margins for different MPs on different soil types

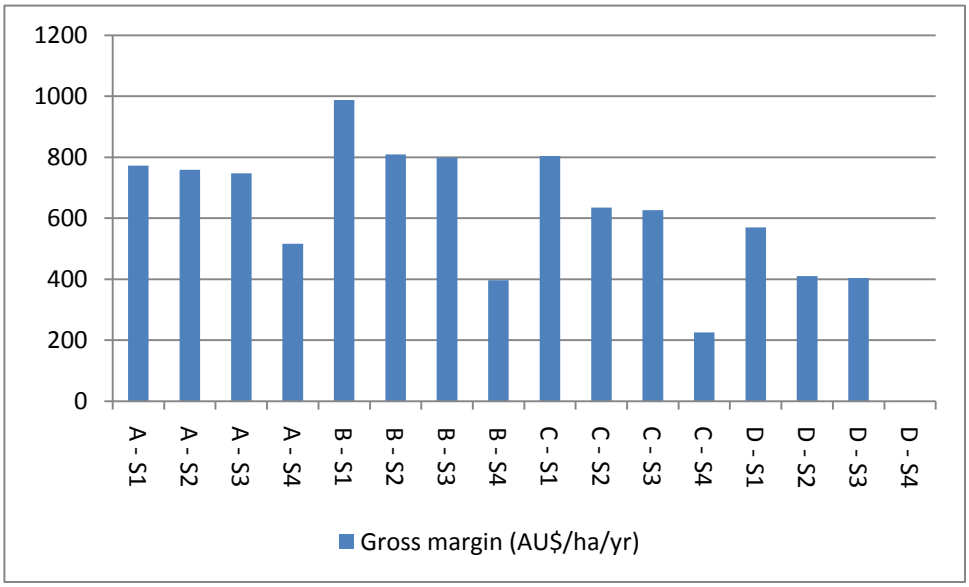


Figure 3: Banana growing gross margins for different MPs on different soil types

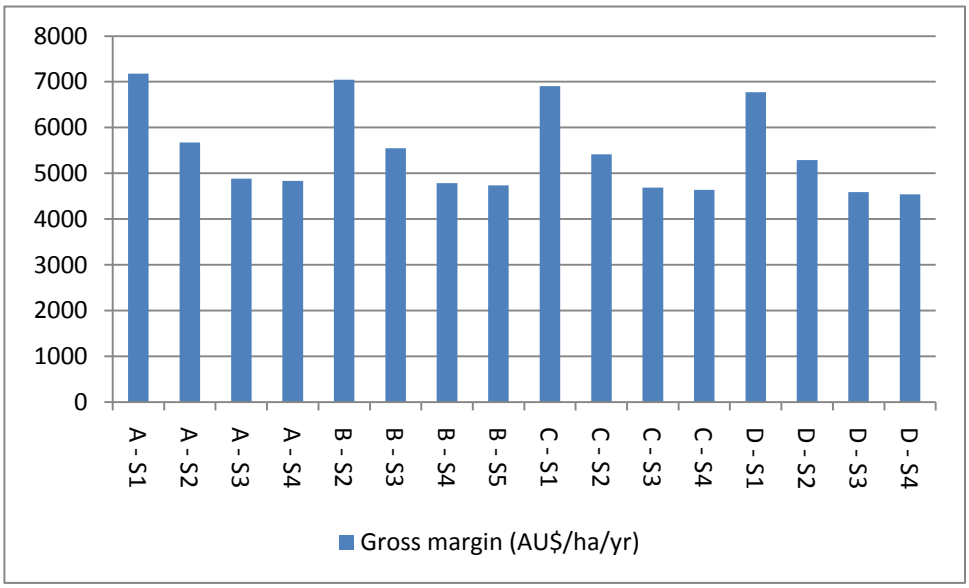
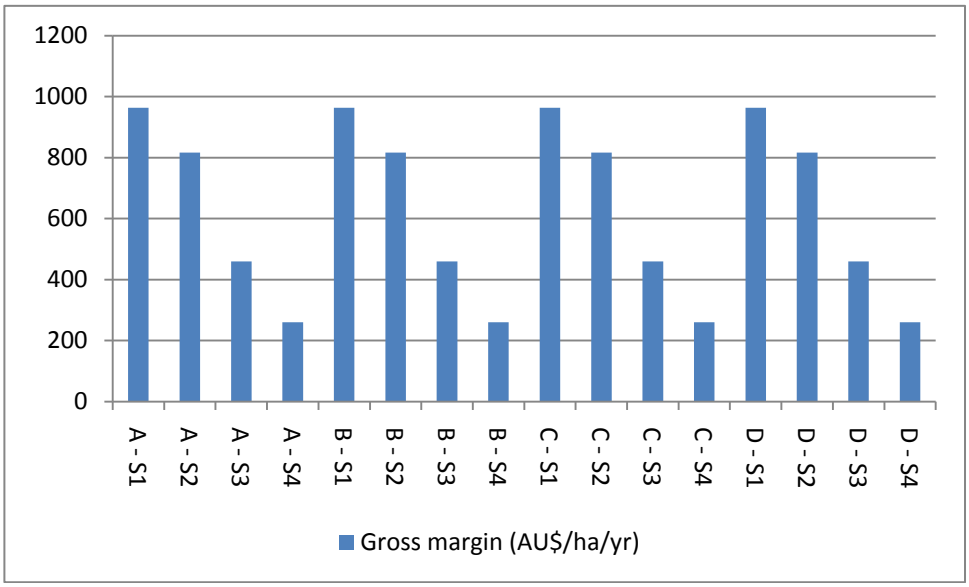


Figure 4: Production forestry gross margins for different MPs on different soil types



2.5. Farm household modelling

To estimate the level of adoption of MPs by different farmers in the Tully-Murray catchment we use a farm household modelling (FHM) approach (based on Roebeling et al. 2004). It assesses how different types of agricultural producers are likely to respond to changes in their decision environment (see Singh et al. 1986; Sadoulet and DeJanvry 1995). The model uses utility functions to enable the exploration of the farmers' decision making process. The utility function is a representation of day-to-day decisions farmers make in their business as well as their household. The farmer will try to maximize his/her utility given specific constraints (e.g. given the limitations of available time). Within the utility function gross income, leisure time and a disincentive to change the status quo are the three objectives that are added. Gross income is defined as the gross value from agricultural production, on- and off-farm employment, minus the costs related to the use of labour and agricultural input. Leisure time is defined as the farm household labour time that is available for other uses than

on- and off-farm employment. A disincentive is defined as a grouping of reasons why farmer may want or may not want to change. Finally, the most important constraints faced by each agricultural producer or farm type are related to the use of production systems, land, labour and agricultural output. Production systems available to agricultural producers are sugarcane (cane farmers and mixed farmers), grazing (mixed farmers and graziers), banana cultivation (mixed farmers) and timber production (mixed farmers). Land use is constrained to the currently available agricultural area. Available farm household labour can be used for on- and off-farm employment, where each farm profile has a specified proportion of off-farm employment. Also, labour can be hired-in for on-farm agricultural production limited to the current level of profile engagement. It must be noted at this point that these constraints will likely mean that enterprises cannot make any change that would require more labour. Enterprises are however able to reduce labour input by switching to low labour land-uses.

For the Tully-Murray case study, the farm economics model estimates production, income, resource use and employment at the farm and regional level for identified agricultural producers in the study area. As mentioned before, farm profiles are developed for agricultural producers, each characterised according to their specific objectives (e.g. labour and leisure time; attitude towards change), their available agricultural production systems and management practices, their socio-economic features and their spatially explicit agro-ecological conditions (through intersection of farm property, land use and soil type data layers using the geographical information system software ArcGIS by ESRI). Regional estimates for production, income, resource use and employment are obtained by aggregating results to the whole of the region.

3. RESULTS

Detailed information on economic, social, environmental, geographic and agronomic indicators can be found in Appendix 1.

In the paragraphs below the results for the different scenarios will be presented and described. This section will be ended by an overview of the scenarios to facilitate a comparison of cost-effectiveness of the different simulated policy instruments and or 'restriction' scenarios

3.1. Current distribution of management practice suites per industry

Currently, not all farmers or farmer profiles manage their land according to one specifice management practice suite. The model has been calibrated to represent a specific distribution of MPs currently under practice, based on personel comments from Tony Webster.

Figure 5: Sugarcane MPs distribution

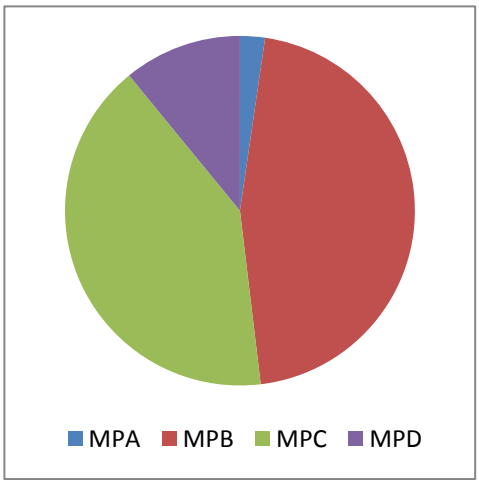


Figure 6: Grazing MPs distribution

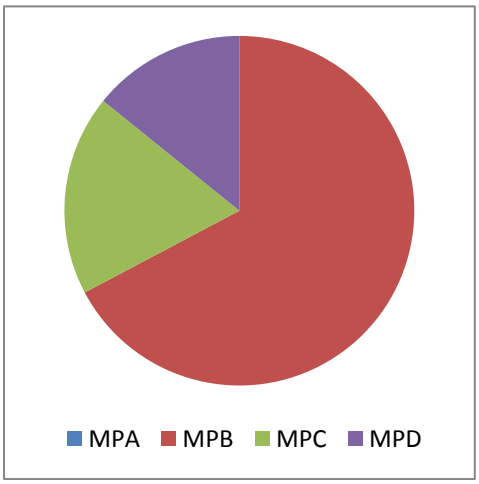


Figure 7: Banana MPs distribution

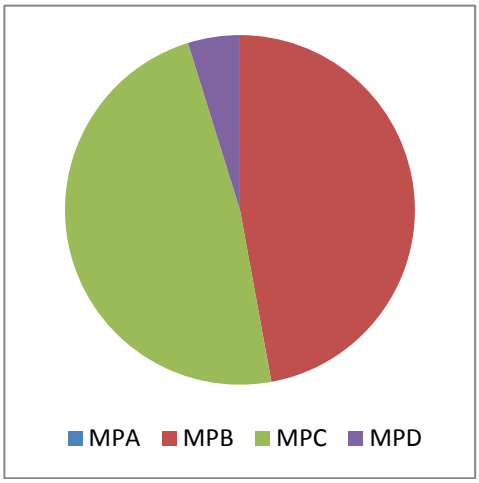
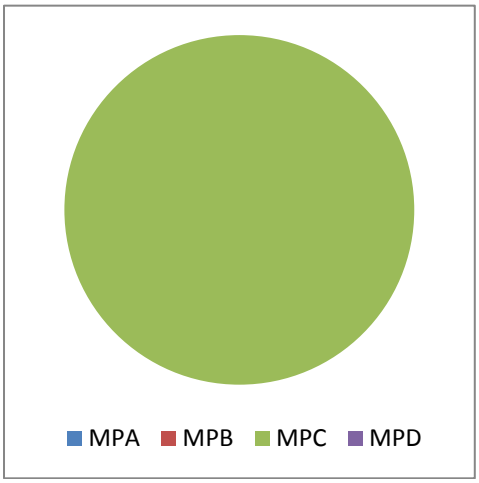


Figure 8: Timber MPs distribution



3.2. Analysis of policy instruments

The FHM approach (as described above) will be used to assess the effectiveness of various price policy instruments (taxes and subsidies) in promoting the adoption of best management practices to achieve DIN water quality improvement. Price instruments include:

- Fertilizer reduction subsidy $1/kg
- Fertilizer reduction subsidy $2/kg
- Fertilizer price tax - 100%
- Fertilizer price tax - 200%

Furthermore, several scenarios have been tested to evaluate consequences of potential regulatory interventions:

- MPs restriction - Suite B
- MPs restriction - Suite A
- Fertilizer application restriction of 20%, 40%, 60% and 80%
- DIN delivery restriction of 20%, 40%, 60% and 80%

Note that the costs for enforcing and monitoring these restrictions are not incorporated in the analysis. Including these costs could lead to different distributional outcomes. Table 10 provides an overview of the economic, social and environmental indicators for each of the scenarios. The base scenario refers to the current situation, where a 100% in the different columns indicate no change, the index. The percentages given for the other scenarios indicate the level of change comparing to the base scenario.

Table 8: Overview of economic, social and environmental indicators for simulated scenarios

Scenario	Economic surplus*	labour	fertiliser use	DIN delivery
BASE	**100%**	**100%**	**100%**	**100%**
Management practice B**	103%	101%	93%	87%
Management practice A**	102%	101%	76%	61%
Fertiliser reduction subsidy $1/kg	101%	96%	85%	82%
Fertiliser reduction subsidy $2/kg	103%	93%	77%	77%
Fertiliser price tax - 100%	89%	96%	84%	81%
Fertiliser price tax - 200%	79%	93%	74%	73%
Fertiliser restriction - 20%	96%	94%	80%	78%
Fertiliser restriction - 40%	86%	83%	60%	55%
Fertiliser restriction - 60%	67%	63%	40%	32%
Fertiliser restriction - 80%	38%	39%	20%	14%
DIN restriction -20%	97%	98%	87%	80%
DIN restriction -40%	92%	96%	73%	60%
DIN restriction -60%	78%	78%	56%	40%
DIN restriction -80%	50%	56%	30%	20%

** Farm income minus the costs for own labour. It represents the returns to land, own capital and management of the farm and to labour employed off-farm (Bouma et al., 1995).*
*** Cost of enforcement and control not incorporated.*

The MP A and MP B are set up to not only lead to improved water quality or other environmental indicators, they are also sensible from a production point of view. In other words, they do not lead to decreased yield. Hence we see that in the scenarios (A and B), there are hardly any changes in economic surplus if each farm type would adopt MP B or MP A. We can actually observe a slight increase in economic surplus, mainly due to decreased fertiliser expenses of these practices. There is a slight increase in labour requirements, where labour is the sum of on farm household labour, hired on farm labour and off farm household labour. With regard to the environmental indicators, we see that with the management of practice B and A fertiliser use drops respectively with 7% and 24%. The delivery of DIN decreases with 13% and 39% respectively.

With the tested policy instrument fertiliser reduction subsidy (the farmer gets rewarded for using less fertiliser, a voluntary instrument) we see an increase of economic surplus of 1% (subsidy of AU$1 per kg of fertiliser used less than the base scenario) and of 3% (subsidy of AU$2 per kg of fertiliser used less than the base scenario). It must be noted that the increase is financed by the taxpayer. Since the farmer is compensated for supplying less fertiliser, not only will farmers change to 'better management practices', which we will explain later in this paragraph, less labour is required to provide the farmer with at least as much utility as in the base scenario.

The fertiliser price tax of 100% (modelled as a price increase of AU$ 1.30 per kg) leads to a substantial drop in economic surplus (11%) and a drop in labour requirement (4%). As expected, fertiliser use drops (16%) as does DIN delivery (19%). The fertiliser price tax of 200% (modelled as a price increase of AU$ 2.60 per kg) leads to a substantial drop in economic surplus (21%) and a drop in labour requirement (7%). As expected, fertiliser use drops (26%) as does DIN delivery (27%).

When comparing these subsidy and tax levels on the basis of cost-effectiveness, see table 11, we can conclude that the fertiliser reduction subsidy provides the most cost-effective incentive for reducing DIN delivery, followed by the fertiliser use tax of AU$ 1.30 per kg. It must be noted that from the perspective of changing from the current MP towards 'better' MPs, the fertiliser tax of AU$ 2.60/kg leads to a positive change of 61%, followed by a fertiliser reduction subsidy of AU$ 2/kg with 59% change, then AU$ 1.30/kg fertiliser tax (58%) and last the fertiliser subsidy of AU$ 1/kg (55%).

Table 9: Costs (private or social) for reducing DIN delivery in AU$ per kg

Scenario	AU$/kg DIN reduction
Fertiliser restriction subsidy $1/kg	$5.88
Fertiliser restriction subsidy $2/kg	$14.14
Fertiliser price tax - 100%	$7.96
Fertiliser price tax - 200%	$17.31

** The provision of a subsidy provides a private benefit at a social cost.*
*** Taxes come at a private cost but at a social benefit.*

When comparing the 'regulatory' scenarios, we can see that the reduction of 80% DIN delivery, as recommended in the Tully WQIP, will come at significant private costs (50% reduction in economic surplus) and at a drop of labour requirements of 44%. It must be noted that a long term drop (64%) in sugarcane production can jeopardize the viability of the mill and the livelihood of the sugar industry with large social consequences to the region.

Table 10: Overview of management practice suite distributions for simulated scenarios

Scenario	MP A	MP B	MP C	MP D
BASE	1%	40%	52%	7%
Management practice B	6%	94%	0%	0%
Management practice A	98%	2%	0%	0%
Fertiliser subsidy $1/kg*	23%	12%	60%	5%
Fertiliser subsidy $2/kg*	36%	3%	62%	0%
Fertiliser price tax - 100%*	24%	20%	51%	5%
Fertiliser price tax - 200%*	37%	3%	54%	6%
Fertiliser restriction - 20%	21%	18%	61%	0%
Fertiliser restriction - 40%	38%	3%	52%	8%
Fertiliser restriction - 60%	45%	1%	15%	14%
Fertiliser restriction - 80%	45%	0%	30%	0%
DIN restriction -20%	7%	24%	54%	14%
DIN restriction -40%	16%	14%	51%	19%
DIN restriction -60%	21%	6%	45%	27%
DIN restriction -80%	46%	0%	37%	17%

**In line with environmental economic theory, we see that a subsidy and a tax lead to similar results.*

As expected, scenarios 'Management practice B' and 'Management practice A' lead to significant changes in the distribution of MPs, however, the enforcement and monitoring of this change may be very costly and time consuming. When we look at the policy instruments fertiliser tax and subsidy we observe a change towards MPA and MPB, however, since fertiliser is less applied in the production of beef and timber, these industries will not respond to the incentive like the sugarcane and banana growing industries. Other voluntary instruments to change the grazing and timber industry towards better MPs need to be analysed.

Restricting fertiliser input and DIN output leads to significant change in the distribution of MPs. However, since agricultural land is taken out of production and economic surplus as well as employment are cut back enormously (38%, 39% and 50%, 56% respectively), this is not be a preferred situation. Once again, it must be noted that since in the grazing and timber industry less fertiliser is applied as in the sugarcane and banana growing industry, other stimuli or regulatory interventions are preferred and worth investigating further.

4. DISCUSSION AND CONCLUSION

In this report we presented an approach that explores which policy instruments are likely to be most effective in stimulating adoption of prioritised land management practice changes. Adoption rates are assessed by predicting the likelihood that different types of farmers will respond to different policy interventions. Furthermore, the corresponding regional socio-economic and environmental consequences of implementing the policy are estimated, such as changes in local income, employment and nitrogen run-off.

The approach is based on the integration of a financial-economic analysis of actual and best management practices in sugarcane, beef cattle production, banana cultivation and production forestry at the plot level and a private economic farm household modelling approach for key agricultural producers at the farm level. This private-economic analysis not only provides insight to the likelihood of adoption of best management practices by agricultural producers and subsequent private-economic and water quality effects, but also enables the identification of incentives and regulations that are likely to be most (cost-) effective in promoting the adoption of best management practices. Policy scenarios include regulations on water quality improvement (via DIN delivery) and fertiliser input, incentives for reducing fertiliser input (subsidies for reducing fertiliser input) and a taxation instrument to reduce fertiliser use. Furthermore, we simulate the situation where all farm types would manage their crops via the preferred code of practice.

When comparing subsidy and tax levels on the basis of cost-effectiveness, we can conclude that the fertiliser restriction subsidy provides the most cost effective incentive for reducing DIN delivery, followed by the fertiliser use tax of AU$ 1.30 per kg. It must be noted that from the perspective of changing from the current MP towards 'better' MPs, the fertiliser tax of AU$ 2.60/kg leads to a biggest change, followed by a fertiliser subsidy of AU$ 2/kg, then the AU$ 1.30/kg fertiliser tax and last the fertiliser subsidy of AU$ 1/kg. Besides the positive response on water quality, the policy instruments fertiliser tax and fertiliser under use subsidy facilitate a change towards MP ‘A’ and MP ‘B’. However, since fertiliser is not a big contributor to the production of beef and timber, these industries will not respond to the incentive like the sugarcane and banana growing industries. Other voluntary instruments to change the grazing and timber industry towards better MPs need to be analysed. Since the focus for change in this report is towards DIN reduction these instruments are not analysed.

When comparing the 'regulatory' scenarios, we can see that the reduction of 80% DIN delivery, as recommended by the Tully WQIP, will come at significant private costs. They will also induce a long term drop in sugarcane production which can jeopardize the viability of the mill and the livelihood of the sugar industry with large social consequences to the region.

Summarizing, while financial motives are important in explaining adoption of management practices, there are a wide range of other non-financial factors explaining the current non-adoption of management practices by a significant number of farmers. The presented private-economic approach allows us to analyse a wide variety of policy scenarios to test their cost-effectiveness in facilitating this change and improving water quality in the region. For the purpose of this project we’ve looked at very specific scenarios, but the analysis could be expanded to, for example, incentives for adoption of riparian vegetation. Also, the methodology could be expanded through:

- Aggregation of farm level results to the catchment and shire level, to determine aggregate income and water quality effects;
- Inclusion of regional constraints which account for, for example, lower bounds on sugarcane supply to the Tully mill;
- Inclusion of downstream costs for the tourism and fishery industry resulting from terrestrial water pollution and reef degradation, as currently under research by MTSRF project 2.5i.4.

A number of biophysical and cost related caveats of this study must be mentioned:

- Production system simulation data, especially for banana growing, grazing and forestry need to be improved and or updated. The data used in this analysis needs to be re-evaluated and more attention should be paid to uncertainty in the modelling and the provision of risk associated with specific practices. Besides, improved production system simulation modelling can assist in better estimations of the amount of DIN available for delivery to the waterways;
- The results are based on a hypothetical situation where each farm type is equally represented in the model, all be it with different farm sizes. A full catchment scale analyses could lead to different outcomes;
- Equivalent production is used for all farm types, but this could potentially differ and needs to be investigated further. Small farmers may not be as productive per hectare as their bigger colleagues or they may face differing cost functions or production constraints;
- Enterprise cost models are assumed identical. It could be expected that small farmers face higher costs per hectare (economies of scale principle) and additional data can increase our knowledge on the implications of enterprise heterogeneity;
- The costs of enforcing and monitoring regulations are not included in the analyses which could have implications on cost-effectiveness, especially on the adoption and delivery process;
- Current labour constraints in the model mean that employing units cannot make any change that would require additional labour - a potentially significant constraint for larger enterprises;
- The utility component that causes farmers to resist change needs to be investigated and quantified more deeply, such as the monitoring of the exact costs of change (training, machinery and other capital requirements, land conversion etc.).
- Extended socio-economic surveying could provide more information on the exact risk aversion of farmers, which could be a large restriction towards change.

The approach used here is deterministic and is, as a result, does not account for uncertainty. Consequently and self-evidently, care should be taken when using the figures presented in this study for policy and planning purposes. Presented results provide an indication of the gross direction and magnitude of change – not an exact recipe for change.

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APPENDIX

Current distribution of management practice suites

Farm Type	ID 1	ID 2	ID 3	ID 4	ID 5
Gross household income (1000AU$)	790	323	93	883	141
Gross farm income (1000AU$)	744	313	65	883	61
On farm household income (1000AU$)	80	27	5	102	10
Economic surplus (1000AU$)	663	286	60	780	51
On farm household labour (hrs/yr)	4873	1620	315	6205	573
On farm hired labour (hrs/yr)	1624	162	81	4971	1064
Off farm household labour (hrs/yr)	1409	312	827	0	2437
Total labour (hrs/yr)	7907	2095	1223	11176	4074
Sugar land use (ha)	450	180	39	267	0
Cattle land use (ha)	0	0	0	122	125
Banana land use (ha)	0	0	0	83	0
Forestry land use (ha)	0	0	0	87	0
Sugar production (kg)	47159	19142	4101	29502	0
Beef production (kg)	0	0	0	98852	120046
Banana production (kg)	0	0	0	2147	0
Timber production (kg)	0	0	0	1250	0
Total fertiliser use (kg)	53426	25644	5558	83662	9006
Total DIN delivery (kg)	9300	4833	1059	9375	611

	Sugar	Cattle	Banana	Forestry	**Total**
Management practice A	2%	0%	0%	0%	**1%**
Management practice B	46%	67%	47%	0%	**40%**
Management practice C	41%	19%	48%	100%	**52%**
Management practice D	11%	14%	5%	0%	**7%**
Total	100%	100%	100%	100%	**100%**

Percentage (%)	ID 1	ID 2	ID 3	ID 4	ID 5
Management practice A	5%	0%	0%	0%	0%
Management practice B	95%	0%	0%	29%	35%
Management practice C	0%	100%	100%	52%	37%
Management practice D	0%	0%	0%	19%	28%
Total	100%	100%	100%	100%	100%

Management practice suite B

Farm Type	ID 1	ID 2	ID 3	ID 4	ID 5
Gross household income (1000AU$)	790	328	94	900	167
Gross farm income (1000AU$)	744	317	66	900	93
On farm household income (1000AU$)	80	27	5	102	13
Economic surplus (1000AU$)	663	291	61	797	80
On farm household labour (hrs/yr)	4873	1620	315	6204	783
On farm hired labour (hrs/yr)	1624	162	81	4971	1300
Off farm household labour (hrs/yr)	1409	310	824	0	2244
Total labour (hrs/yr)	7907	2093	1220	11176	4327
Sugar land use (ha)	450	180	39	267	0
Cattle land use (ha)	0	0	0	122	159
Banana land use (ha)	0	0	0	83	0
Forestry land use (ha)	0	0	0	87	0
Sugar production (kg)	47146	19127	4099	29367	0
Beef production (kg)	0	0	0	98852	123321
Banana production (kg)	0	0	0	2147	0
Timber production (kg)	0	0	0	1250	0
Total fertiliser use (kg)	53273	21552	4680	70106	14937
Total DIN delivery (kg)	9263	3701	816	6904	1145

	Sugar	Cattle	Banana	Forestry	Total
Management practice A	3%	12%	9%	0%	6%
Management practice B	97%	88%	91%	100%	94%
Management practice C	0%	0%	0%	0%	0%
Management practice D	0%	0%	0%	0%	0%
Total	100%	100%	100%	100%	100%

Percentage (%)	ID 1	ID 2	ID 3	ID 4	ID 5
Management practice A	6%	0%	0%	1%	21%
Management practice B	94%	100%	100%	99%	79%
Management practice C	0%	0%	0%	0%	0%
Management practice D	0%	0%	0%	0%	0%
Total	100%	100%	100%	100%	100%

Management practice suite A

Farm Type	ID 1	ID 2	ID 3	ID 4	ID 5
Gross household income (1000AU$)	790	328	94	895	149
Gross farm income (1000AU$)	744	318	67	895	74
On farm household income (1000AU$)	80	27	5	102	13
Economic surplus (1000AU$)	664	291	61	792	61
On farm household labour (hrs/yr)	4873	1620	315	6205	783
On farm hired labour (hrs/yr)	1624	162	81	4971	1300
Off farm household labour (hrs/yr)	1409	310	824	0	2250
Total labour (hrs/yr)	7907	2093	1219	11176	4333
Sugar land use (ha)	450	180	39	267	0
Cattle land use (ha)	0	0	0	122	159
Banana land use (ha)	0	0	0	83	0
Forestry land use (ha)	0	0	0	87	0
Sugar production (kg)	46286	18767	4021	28940	0
Beef production (kg)	0	0	0	80700	103065
Banana production (kg)	0	0	0	2147	0
Timber production (kg)	0	0	0	1250	0
Total fertiliser use (kg)	40590	15920	3411	60781	14783
Total DIN delivery (kg)	6152	2321	505	5144	1123

	Sugar	Cattle	Banana	Forestry	Total
Management practice A	97%	96%	100%	100%	98%
Management practice B	3%	4%	0%	0%	2%
Management practice C	0%	0%	0%	0%	0%
Management practice D	0%	0%	0%	0%	0%
Total	100%	100%	100%	100%	100%

Percentage (%)	ID1	ID2	ID 3	ID 4	ID 5
Management practice A	93%	100%	100%	98%	100%
Management practice B	7%	0%	0%	2%	0%
Management practice C	0%	0%	0%	0%	0%
Management practice D	0%	0%	0%	0%	0%
Total	100%	100%	100%	100%	100%

Fertiliser tax - 100%

Farm Type	ID 1	ID 2	ID 3	ID 4	ID 5
Gross household income (1000AU$)	739	290	86	785	130
Gross farm income (1000AU$)	693	279	58	785	49
On farm household income (1000AU$)	80	27	5	102	10
Economic surplus (1000AU$)	612	253	53	682	40
On farm household labour (hrs/yr)	4873	1620	315	6209	578
On farm hired labour (hrs/yr)	1624	162	81	3807	1059
Off farm household labour (hrs/yr)	1411	325	852	0	2437
Total labour (hrs/yr)	7908	2108	1247	10016	4074
Sugar land use (ha)	450	180	39	267	0
Cattle land use (ha)	0	0	0	64	125
Banana land use (ha)	0	0	0	83	0
Forestry land use (ha)	0	0	0	87	0
Sugar production (kg)	46212	19140	4101	29390	0
Beef production (kg)	0	0	0	61063	120046
Banana production (kg)	0	0	0	2147	0
Timber production (kg)	0	0	0	1250	0
Total fertiliser use (kg)	39294	25584	5558	69240	9006
Total DIN delivery (kg)	5829	4817	1059	8190	611

	Sugar	Cattle	Banana	Forestry	Total
Management practice A	47%	0%	47%	0%	24%
Management practice B	1%	27%	53%	0%	20%
Management practice C	52%	54%	0%	100%	51%
Management practice D	0%	19%	0%	0%	5%
Total	100%	100%	100%	100%	100%

Percentage (%)	ID1	ID2	ID3	ID4	ID5
Management practice A	98%	0%	0%	8%	0%
Management practice B	2%	1%	0%	10%	35%
Management practice C	0%	99%	100%	82%	37%
Management practice D	0%	0%	0%	0%	28%
Total	100%	100%	100%	100%	100%

Fertiliser tax - 200%

Farm Type	ID 1	ID 2	ID 3	ID 4	ID 5
Gross household income (1000AU$)	689	258	80	711	118
Gross farm income (1000AU$)	642	246	51	711	38
On farm household income (1000AU$)	80	27	5	103	10
Economic surplus (1000AU$)	562	220	46	608	28
On farm household labour (hrs/yr)	4873	1620	315	6212	583
On farm hired labour (hrs/yr)	1624	162	81	3004	1054
Off farm household labour (hrs/yr)	1412	340	877	0	2437
Total labour (hrs/yr)	7910	2122	1273	9216	4074
Sugar land use (ha)	450	180	39	267	0
Cattle land use (ha)	0	0	0	64	125
Banana land use (ha)	0	0	0	43	0
Forestry land use (ha)	0	0	0	87	0
Sugar production (kg)	46209	19139	4101	29130	0
Beef production (kg)	0	0	0	69501	121539
Banana production (kg)	0	0	0	1313	0
Timber production (kg)	0	0	0	1250	0
Total fertiliser use (kg)	39214	25541	5558	52152	8795
Total DIN delivery (kg)	5811	4805	1059	6021	568

	Sugar	Cattle	Banana	Forestry	Total
Management practice A	58%	0%	91%	0%	37%
Management practice B	1%	0%	9%	0%	3%
Management practice C	41%	76%	0%	100%	54%
Management practice D	0%	24%	0%	0%	6%
Total	100%	100%	100%	100%	100%

Percentage (%)	ID1	ID2	ID3	ID4	ID5
Management practice A	100%	0%	0%	29%	0%
Management practice B	0%	1%	0%	3%	0%
Management practice C	0%	99%	100%	58%	100%
Management practice D	0%	0%	0%	10%	0%
Total	100%	100%	100%	100%	100%

Fertiliser use reduction subsidy 1$/kg

Farm Type	ID 1	ID 2	ID 3	ID 4	ID 5
Gross household income (1000AU$)	804	323	93	890	141
Gross farm income (1000AU$)	757	313	65	890	61
On farm household income (1000AU$)	80	27	5	102	10
Economic surplus (1000AU$)	677	286	60	787	51
On farm household labour (hrs/yr)	4873	1620	315	6205	573
On farm hired labour (hrs/yr)	1624	162	81	3811	1064
Off farm household labour (hrs/yr)	1409	312	827	0	2437
Total labour (hrs/yr)	7906	2095	1223	10016	4074
Sugar land use (ha)	450	180	39	267	0
Cattle land use (ha)	0	0	0	64	125
Banana land use (ha)	0	0	0	83	0
Forestry land use (ha)	0	0	0	87	0
Sugar production (kg)	46257	19141	4101	29390	0
Beef production (kg)	0	0	0	55152	120046
Banana production (kg)	0	0	0	2147	0
Timber production (kg)	0	0	0	1250	0
Total fertiliser use (kg)	39826	25602	5558	71066	9006
Total DIN delivery (kg)	5958	4822	1059	8268	611

	Sugar	Cattle	Banana	Forestry	Total
Management practice A	45%	0%	47%	0%	23%
Management practice B	3%	46%	0%	0%	12%
Management practice C	52%	35%	53%	100%	60%
Management practice D	0%	19%	0%	0%	5%
Total	100%	100%	100%	100%	100%

Percentage (%)	ID1	ID2	ID3	ID4	ID5
Management practice A	93%	0%	0%	8%	0%
Management practice B	7%	1%	0%	9%	35%
Management practice C	0%	99%	100%	84%	37%
Management practice D	0%	0%	0%	0%	28%
Total	100%	100%	100%	100%	100%

Fertiliser use reduction subsidy 2$/kg

Farm Type	ID 1	ID 2	ID 3	ID 4	ID 5
Gross household income (1000AU$)	819	323	93	909	141
Gross farm income (1000AU$)	772	313	65	909	61
On farm household income (1000AU$)	80	27	5	102	10
Economic surplus (1000AU$)	692	286	60	807	51
On farm household labour (hrs/yr)	4873	1620	315	6204	573
On farm hired labour (hrs/yr)	1624	162	81	3012	1065
Off farm household labour (hrs/yr)	1408	312	827	0	2437
Total labour (hrs/yr)	7906	2094	1223	9216	4074
Sugar land use (ha)	450	180	39	267	0
Cattle land use (ha)	0	0	0	64	125
Banana land use (ha)	0	0	0	43	0
Forestry land use (ha)	0	0	0	87	0
Sugar production (kg)	46212	19140	4101	29274	0
Beef production (kg)	0	0	0	62228	121539
Banana production (kg)	0	0	0	1313	0
Timber production (kg)	0	0	0	1250	0
Total fertiliser use (kg)	39294	25557	5558	56770	8795
Total DIN delivery (kg)	5829	4809	1059	7067	568

	Sugar	Cattle	Banana	Forestry	Total
Management practice A	51%	0%	91%	0%	36%
Management practice B	2%	0%	9%	0%	3%
Management practice C	46%	100%	0%	100%	62%
Management practice D	0%	0%	0%	0%	0%
Total	100%	100%	100%	100%	100%

Percentage (%)	ID1	ID2	ID3	ID4	ID5
Management practice A	98%	0%	0%	17%	0%
Management practice B	2%	1%	0%	3%	0%
Management practice C	0%	99%	100%	80%	100%
Management practice D	0%	0%	0%	0%	0%
Total	100%	100%	100%	100%	100%

Fertiliser use restriction -20%

Farm Type	ID 1	ID 2	ID 3	ID 4	ID 5
Gross household income (1000AU$)	790	288	85	871	136
Gross farm income (1000AU$)	743	267	55	871	56
On farm household income (1000AU$)	80	21	4	102	10
Economic surplus (1000AU$)	663	245	51	768	46
On farm household labour (hrs/yr)	4873	1292	236	6205	575
On farm hired labour (hrs/yr)	1624	162	81	3657	792
Off farm household labour (hrs/yr)	1409	654	934	0	2437
Total labour (hrs/yr)	7907	2109	1251	9863	3804
Sugar land use (ha)	450	147	31	267	0
Cattle land use (ha)	0	0	0	64	104
Banana land use (ha)	0	0	0	75	0
Forestry land use (ha)	0	0	0	87	0
Sugar production (kg)	46502	16179	3408	29379	0
Beef production (kg)	0	0	0	61492	101514
Banana production (kg)	0	0	0	1987	0
Timber production (kg)	0	0	0	1250	0
Total fertiliser use (kg)	42741	20515	4446	66930	7205
Total DIN delivery (kg)	6661	3693	816	7993	471

	Sugar	Cattle	Banana	Forestry	Total
Management practice A	33%	0%	52%	0%	21%
Management practice B	19%	3%	48%	0%	18%
Management practice C	48%	97%	0%	100%	61%
Management practice D	0%	0%	0%	0%	0%
Total	100%	100%	100%	100%	100%

Percentage (%)	ID1	ID2	ID3	ID4	ID5
Management practice A	64%	3%	0%	8%	0%
Management practice B	36%	1%	0%	11%	0%
Management practice C	0%	96%	100%	82%	100%
Management practice D	0%	0%	0%	0%	0%
Total	100%	100%	100%	100%	100%

Fertiliser use restriction -40%

Farm Type	ID 1	ID 2	ID 3	ID 4	ID 5
Gross household income (1000AU$)	694	248	78	843	129
Gross farm income (1000AU$)	641	221	44	843	48
On farm household income (1000AU$)	77	18	3	102	10
Economic surplus (1000AU$)	564	203	41	740	39
On farm household labour (hrs/yr)	4637	1092	156	6207	579
On farm hired labour (hrs/yr)	450	8	81	2408	404
Off farm household labour (hrs/yr)	1624	812	1043	0	2437
Total labour (hrs/yr)	6711	1913	1280	8614	3419
Sugar land use (ha)	352	111	23	267	0
Cattle land use (ha)	0	0	0	34	75
Banana land use (ha)	0	0	0	43	0
Forestry land use (ha)	0	0	0	87	0
Sugar production (kg)	37782	12998	2714	29130	0
Beef production (kg)	0	0	0	38441	72931
Banana production (kg)	0	0	0	1313	0
Timber production (kg)	0	0	0	1250	0
Total fertiliser use (kg)	32056	15386	3334	50197	5404
Total DIN delivery (kg)	4503	2569	572	5894	367

	Sugar	Cattle	Banana	Forestry	Total
Management practice A	60%	0%	91%	0%	38%
Management practice B	2%	0%	9%	0%	3%
Management practice C	39%	69%	0%	100%	52%
Management practice D	0%	31%	0%	0%	8%
Total	100%	100%	100%	100%	100%

Percentage (%)	ID1	ID2	ID3	ID4	ID5
Management practice A	100%	5%	0%	31%	0%
Management practice B	0%	2%	0%	4%	0%
Management practice C	0%	94%	100%	58%	100%
Management practice D	0%	0%	0%	8%	0%
Total	100%	100%	100%	100%	100%

Fertiliser use restriction --60%

Farm Type	ID 1	ID 2	ID 3	ID 4	ID 5
Gross household income (1000AU$)	496	180	69	741	119
Gross farm income (1000AU$)	443	154	30	741	38
On farm household income (1000AU$)	52	12	1	98	10
Economic surplus (1000AU$)	391	141	29	643	28
On farm household labour (hrs/yr)	3164	737	77	5963	583
On farm hired labour (hrs/yr)	0	0	81	0	72
Off farm household labour (hrs/yr)	1624	812	1163	0	2437
Total labour (hrs/yr)	4788	1549	1321	5963	3092
Sugar land use (ha)	219	74	16	191	0
Cattle land use (ha)	0	0	0	65	50
Banana land use (ha)	0	0	0	43	0
Forestry land use (ha)	0	0	0	0	0
Sugar production (kg)	25195	8935	1897	22360	0
Beef production (kg)	0	0	0	73287	48621
Banana production (kg)	0	0	0	1313	0
Timber production (kg)	0	0	0	0	0
Total fertiliser use (kg)	21370	10258	2223	33465	3602
Total DIN delivery (kg)	2753	1650	360	3005	245

	Sugar	Cattle	Banana	Forestry	Total
Management practice A	81%	0%	100%	0%	45%
Management practice B	2%	0%	0%	0%	1%
Management practice C	16%	44%	0%	0%	15%
Management practice D	0%	56%	0%	0%	14%
Total	100%	100%	100%	0%	75%

Percentage (%)	ID1	ID2	ID3	ID4	ID5
Management practice A	100%	10%	0%	75%	0%
Management practice B	0%	0%	0%	4%	0%
Management practice C	0%	90%	100%	0%	100%
Management practice D	0%	0%	0%	22%	0%
Total	100%	100%	100%	100%	100%

Fertiliser use restriction --80%

Farm Type	ID 1	ID 2	ID 3	ID 4	ID 5
Gross household income (1000AU$)	275	110	57	429	101
Gross farm income (1000AU$)	221	83	15	429	20
On farm household income (1000AU$)	26	6	0	30	5
Economic surplus (1000AU$)	195	77	15	399	15
On farm household labour (hrs/yr)	1582	386	0	1837	328
On farm hired labour (hrs/yr)	0	0	79	0	0
Off farm household labour (hrs/yr)	1624	812	1292	0	2437
Total labour (hrs/yr)	3206	1198	1371	1837	2764
Sugar land use (ha)	110	39	8	49	0
Cattle land use (ha)	0	0	0	0	25
Banana land use (ha)	0	0	0	43	0
Forestry land use (ha)	0	0	0	0	0
Sugar production (kg)	12597	4780	984	6199	0
Beef production (kg)	0	0	0	0	24310
Banana production (kg)	0	0	0	1313	0
Timber production (kg)	0	0	0	0	0
Total fertiliser use (kg)	10685	5129	1111	16732	1801
Total DIN delivery (kg)	1376	773	171	1036	122

	Sugar	Cattle	Banana	Forestry	Total
Management practice A	82%	0%	100%	0%	45%
Management practice B	0%	0%	0%	0%	0%
Management practice C	18%	100%	0%	0%	30%
Management practice D	0%	0%	0%	0%	0%
Total	100%	100%	100%	0%	75%

Percentage (%)	ID1	ID2	ID3	ID4	ID5
Management practice A	100%	24%	0%	100%	0%
Management practice B	0%	0%	0%	0%	0%
Management practice C	0%	76%	100%	0%	100%
Management practice D	0%	0%	0%	0%	0%
Total	100%	100%	100%	100%	100%

DIN delivery restriction -20%

Farm Type	ID 1	ID 2	ID 3	ID 4	ID 5
Gross household income (1000AU$)	790	296	87	873	137
Gross farm income (1000AU$)	743	277	56	873	57
On farm household income (1000AU$)	80	23	4	102	10
Economic surplus (1000AU$)	663	254	52	771	47
On farm household labour (hrs/yr)	4873	1368	250	6205	575
On farm hired labour (hrs/yr)	1624	162	81	4710	863
Off farm household labour (hrs/yr)	1409	575	916	0	2437
Total labour (hrs/yr)	7907	2106	1247	10916	3874
Sugar land use (ha)	450	155	33	267	0
Cattle land use (ha)	0	0	0	109	110
Banana land use (ha)	0	0	0	83	0
Forestry land use (ha)	0	0	0	87	0
Sugar production (kg)	46707	16855	3531	29254	0
Beef production (kg)	0	0	0	95240	106705
Banana production (kg)	0	0	0	2147	0
Timber production (kg)	0	0	0	1250	0
Total fertiliser use (kg)	45906	22049	4802	73203	7528
Total DIN delivery (kg)	7440	3866	847	7500	489

	Sugar	Cattle	Banana	Forestry	Total
Management practice A	30%	0%	0%	0%	7%
Management practice B	29%	30%	38%	0%	24%
Management practice C	38%	70%	10%	100%	54%
Management practice D	3%	0%	53%	0%	14%
Total	100%	100%	100%	100%	100%

Percentage (%)	ID1	ID2	ID3	ID4	ID5
Management practice A	44%	12%	11%	8%	0%
Management practice B	56%	1%	0%	20%	0%
Management practice C	0%	72%	67%	64%	100%
Management practice D	0%	16%	22%	8%	0%
Total	100%	100%	100%	100%	100%

DIN delivery restriction -40%

Farm Type	ID 1	ID 2	ID 3	ID 4	ID 5
Gross household income (1000AU$)	773	261	80	858	129
Gross farm income (1000AU$)	720	235	47	858	48
On farm household income (1000AU$)	77	18	3	102	10
Economic surplus (1000AU$)	643	217	44	755	39
On farm household labour (hrs/yr)	4634	1085	181	6206	579
On farm hired labour (hrs/yr)	1614	142	81	4710	403
Off farm household labour (hrs/yr)	1624	812	1010	0	2437
Total labour (hrs/yr)	7872	2039	1272	10916	3418
Sugar land use (ha)	433	124	26	267	0
Cattle land use (ha)	0	0	0	109	75
Banana land use (ha)	0	0	0	83	0
Forestry land use (ha)	0	0	0	87	0
Sugar production (kg)	44718	14128	2927	29125	0
Beef production (kg)	0	0	0	112083	72870
Banana production (kg)	0	0	0	2147	0
Timber production (kg)	0	0	0	1250	0
Total fertiliser use (kg)	37948	17642	3835	64918	5399
Total DIN delivery (kg)	5580	2900	635	5625	367

	Sugar	Cattle	Banana	Forestry	Total
Management practice A	64%	0%	0%	0%	16%
Management practice B	18%	0%	38%	0%	14%
Management practice C	14%	80%	10%	100%	51%
Management practice D	4%	20%	53%	0%	19%
Total	100%	100%	100%	100%	100%

Percentage (%)	ID1	ID2	ID3	ID4	ID5
Management practice A	100%	15%	14%	17%	0%
Management practice B	0%	2%	0%	33%	0%
Management practice C	0%	64%	59%	35%	100%
Management practice D	0%	19%	27%	15%	0%
Total	100%	100%	100%	100%	100%

DIN delivery restriction -60%

Farm Type	ID 1	ID 2	ID 3	ID 4	ID 5
Gross household income (1000AU$)	625	209	72	801	118
Gross farm income (1000AU$)	571	182	35	801	38
On farm household income (1000AU$)	70	15	2	102	10
Economic surplus (1000AU$)	501	168	34	699	28
On farm household labour (hrs/yr)	4242	879	104	6208	583
On farm hired labour (hrs/yr)	0	0	81	2605	71
Off farm household labour (hrs/yr)	1624	812	1119	0	2437
Total labour (hrs/yr)	5866	1691	1304	8813	3091
Sugar land use (ha)	294	89	18	207	0
Cattle land use (ha)	0	0	0	64	50
Banana land use (ha)	0	0	0	83	0
Forestry land use (ha)	0	0	0	87	0
Sugar production (kg)	32735	10597	2207	23750	0
Beef production (kg)	0	0	0	72599	48580
Banana production (kg)	0	0	0	2147	0
Timber production (kg)	0	0	0	1250	0
Total fertiliser use (kg)	27768	12053	2600	54082	3599
Total DIN delivery (kg)	3720	1933	424	3750	244

	Sugar	Cattle	Banana	Forestry	Total
Management practice A	85%	0%	0%	0%	21%
Management practice B	0%	0%	26%	0%	6%
Management practice C	15%	44%	21%	100%	45%
Management practice D	0%	56%	53%	0%	27%
Total	100%	100%	100%	100%	100%

Percentage (%)	ID1	ID2	ID3	ID4	ID5
Management practice A	100%	15%	0%	47%	0%
Management practice B	0%	0%	0%	5%	0%
Management practice C	0%	85%	100%	24%	100%
Management practice D	0%	0%	0%	24%	0%
Total	100%	100%	100%	100%	100%

DIN delivery restriction -80%

Farm Type	ID 1	ID 2	ID 3	ID 4	ID 5
Gross household income (1000AU$)	353	132	60	623	102
Gross farm income (1000AU$)	299	106	18	623	21
On farm household income (1000AU$)	35	8	0	91	7
Economic surplus (1000AU$)	264	97	18	532	15
On farm household labour (hrs/yr)	2137	496	15	5540	403
On farm hired labour (hrs/yr)	0	0	81	0	0
Off farm household labour (hrs/yr)	1624	812	1265	0	2437
Total labour (hrs/yr)	3762	1309	1362	5540	2839
Sugar land use (ha)	148	50	10	87	0
Cattle land use (ha)	0	0	0	61	31
Banana land use (ha)	0	0	0	43	0
Forestry land use (ha)	0	0	0	87	0
Sugar production (kg)	17022	6078	1182	10966	0
Beef production (kg)	0	0	0	68791	29899
Banana production (kg)	0	0	0	1313	0
Timber production (kg)	0	0	0	1250	0
Total fertiliser use (kg)	14438	6428	1353	29204	1993
Total DIN delivery (kg)	1860	967	212	1875	122

	Sugar	Cattle	Banana	Forestry	Total
Management practice A	85%	0%	100%	0%	46%
Management practice B	0%	0%	0%	0%	0%
Management practice C	15%	34%	0%	100%	37%
Management practice D	0%	66%	0%	0%	17%
Total	100%	100%	100%	100%	100%

Percentage (%)	ID1	ID2	ID3	ID4	ID5
Management practice A	100%	32%	0%	47%	0%
Management practice B	0%	0%	0%	0%	0%
Management practice C	0%	68%	100%	31%	100%
Management practice D	0%	0%	0%	22%	0%
Total	100%	100%	100%	100%	100%

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