Survey of Farmer Management of Phosphorus Application in the Hopkins River Catchment, for Use in Game-theoretic Modeling.

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EXTENDED ABSTRACT

The 2002 audit of nutrient loads to Australian rivers and estuaries indicates total export of phosphorus within the waterways of western Victoria is estimated at 1.9 times the natural export that occurred prior to European settlement (Audit of Australian Rivers and Estuaries 2002). The Hopkins River basin, found within this region, has a high proportion of land clearing within the basin which has exacerbated the loss of nutrients to waterways through soil erosion and nutrient runoff. This has potential to increase with land use change to more intensive grazing, cropping and forestry.

Although there is a move to conservation farming, increases in the amount of phosphorus applied for more intensive agriculture has the potential to cause further runoff of nutrients into the streams which in turn has potential to increase the incidence of blue-green algae outbreaks within the region. This trend is indicated by current water testing data from the Hopkins River and its tributaries.

The game theoretic approach has successfully been used in resolution of environmental problems worldwide where there is an economic impact to the decision making process. In this case, the amount and the timing of phosphorus application are the parameters being explored in a cooperative game theory equation. These are to be varied with the resulting impact on ‘economics of production’ versus ‘cost of nutrient pollution’ investigated. Dependant on the payoff function, the potential for cooperative action on phosphorus management by groups of farmers, will be assessed.

During the research, a survey was undertaken in the Hopkins River basin to determine the current management of phosphorus fertilisers, understanding of nutrient pollution, attitude to natural resource management and the basis farmers use to make fertiliser management decisions on grazing and mixed enterprise properties. The aim of the survey is to find the most plausible player structure in the game proposed, and what the potential is for player coalitions, so that cooperative action relating to application of phosphorus fertilizer can be undertaken.

The results for this group of landholders show that:

- The quantity of phosphorus (kg /ha) applied for pasture and for crop is close to the range advised by the Department of Primary Industries in this area.
- There is a high use of contractors to spread fertiliser.
- Decisions on the amount of fertiliser used are influenced by numerous factors; advice from agronomists, budget, soil tests, seasonal climate, stocking rate and past experience.
- 80% of participants do not view nutrient pollution as relevant to them and their community currently.
- 66% of these farmers are fencing and re-vegetating waterways
- The study group of farmers indicated a good knowledge of the agricultural practices which contribute to nutrient pollution.

In this research group the most plausible player structure in the game is to group the properties which include a cropping enterprise together and those which are predominantly grazing together. Player coalitions between properties that have a similar enterprise mix is possible, so that timing of fertilizer applications may be coordinated to minimize runoff during periods of potential high rainfall events. Contractors would need to be involved in the process.

In conclusion, the process has raised awareness amongst the farming population of regional nutrient pollution caused by runoff from agricultural land, and enlists their assistance in realizing a cooperative approach to the problem. This supports the programs developed by Glenelg Hopkins Catchment Management Authority for nutrient reduction of streams in south west Victoria.

1. INTRODUCTION

The 2002 audit of nutrient loads to Australian rivers and estuaries indicates that dissolved phosphorus (144 t/yr) occurring in the waterways of western Victoria is predominantly due to runoff rather than being a point source problem. The high percentage of agricultural landuse within the Hopkins basin supports this figure. A larger proportion of phosphorus being exported through the river systems is due to particulate phosphorus (730 t/yr) which is released from soil erosion of stream banks, gullies, hill slopes, and released from disturbed sediments on the floodplain and within reservoirs. The total export of phosphorus is estimated at 1.9 times the natural export that occurred prior to European settlement (Audit of Australian Rivers and Estuaries 2002).

Blue green algae outbreaks in streams can be attributed to increased nutrient status, lower water flows and raised water temperature. The incidence of blue green algae occurring in the Glenelg Hopkins region is increasing. Land use change (principally from grazing to cropping and forestry) has increased the potential of nutrient pollution due to changed ground cover, fertiliser use and timing of soil disturbance (Ierodiaconou, 2004). Reduced rainfall, more frequent extreme rainfall events and higher temperatures associated with climate change are likely to exacerbate this trend.

Water testing data of the Total Phosphorus (TP) levels in the Hopkins River and at other sites within the Hopkins basin reflects the figures above. They indicate increasing incidence of TP above the Australian and New Zealand Guidelines for fresh and marine water quality target levels of 0.037mg/l phosphorus for blue green algae occurrence during longer periods of the year (Melland, 2003).

(Melland, 2005) has found that the 'dissolved reactive phosphorus fraction is the phosphorus fraction in runoff that increases the most as pasture phosphorus fertility increases' and 'that factors such as runoff volume and fertiliser management practices (eg timing of application) should be considered in predictive models' of potential runoff.

During the research, a survey was undertaken in the Hopkins River basin to determine

- the current management of Phosphorus fertilisers on grazing and mixed enterprise properties,
- understanding of nutrient pollution amongst farmers
- attitude to natural resource management of the farmers within the catchment
- the basis farmers used to make fertiliser management decisions.

The game theoretic approach has successfully been used in resolution of environmental problems worldwide. In this case, the amount and the timing of phosphorus application are the parameters being explored in the cooperative game theory equation. These are to be varied with the resulting impact on 'economics of production' versus 'cost of nutrient pollution' investigated. Dependant on the payoff function, potential for cooperative action on phosphorus management by groups of farmers, will be assessed.

2. METHOD

The research team approached established farmer groups in south west Victoria to obtain information on the fertiliser practices on individual properties within the Hopkins River basin. 'Southern Farming Systems', Glenthompson Bestwool/Bestlamb Group, Muston's Creek Landcare Group, Bushy Creek Landcare Group and the South Eckland Dairy Discussion Group were approached. This gave us 200 potential participants spread throughout the Hopkins River basin. Replies were obtained from 34 of the participants, of which 30 were useable in the project.

The initial survey was split into three sections.

- Part A requested information on property size, location, farming enterprise, presence of waterways, soil types, rainfall and pasture
- Part B requested information associated with fertiliser practices; type used, amount, season of spreading, annual variation and decision making parameters
- Part C requested information on farmer attitudes to the environment and natural resource management

The data have been collated in a spreadsheet with private information removed once the position of properties within the Hopkins basin has been determined. A second survey sought clarification of several answers from the first survey. Namely, specific timing of fertilizer application, current soil phosphorus and target soil phosphorus.

Results of the surveys were subjected to statistical analysis and incorporated into a GIS map for comparison and visual representation.
The numerical data has been analysed using Minitab™ and excel data analysis. ArcGIS™ has been used to produce maps of Property size (Figure

1), Enterprise analysis (Figure 2), and Phosphorus use (Figure 4).

3. RESULTS

3.1 General information

The Hopkins river basin has a total area of 986,000ha. It is found in the south west of Victoria, Australia. The area represented by project participants is 24,651 Ha or 2.5% of the total. The farms correspond to 14,225 Ha grazing and 9,969Ha cropping. The average farm size is 821Ha and they fall in a range of 96 to 2446 Ha . Due to the lack of farms in the lower basin being represented the average is slightly high for the south west region.

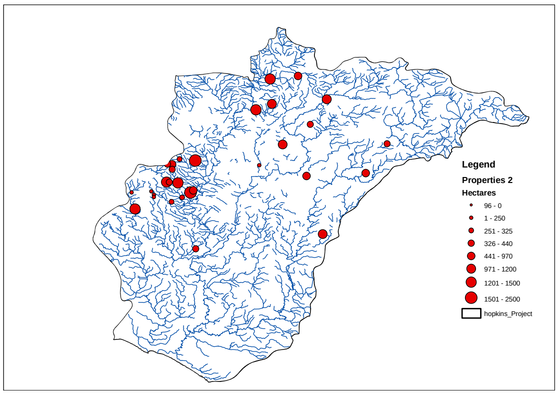


Figure 1: Property by size

The returned surveys are from the groups in the north of the Hopkins River basin (Figure 1). The farmers in the dairy discussion group chose not to participate. This group is outside the local region in which the researchers are known and the farmers indicated that the topic may lead to targeting of the group for over-use of fertilisers and nutrient run-off.

(Melland, 2005) discussed the importance of some familiarity of the researcher within the region which lends trust and credibility to a research project, the experience of the project would support this. More dairy farmers will be approached for inclusion in the future.

3.2 Enterprise

80 % of all properties run a wool enterprise, 70 % run a prime lamb enterprise, 66.6 % crop cereal grain, 23% run a beef enterprise and 13.3% grow forage crops . Most farmers run several enterprises (only 3 farmers ran a single enterprise operation). 91% of pastures are introduced and 68% are perennial.

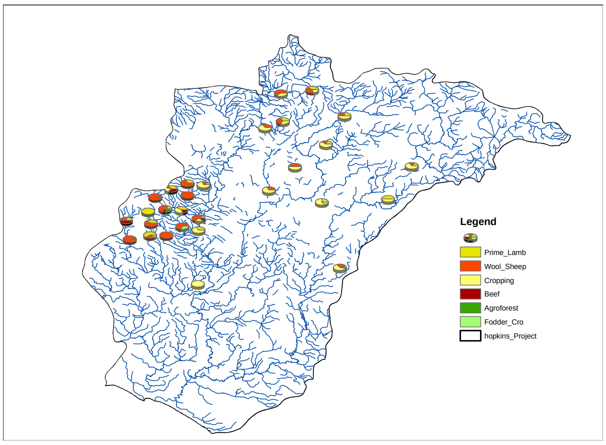


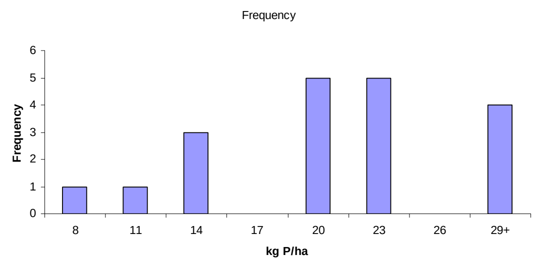
Figure 2: Hopkins River Basin and Properties by enterprise

3.3 Quantity

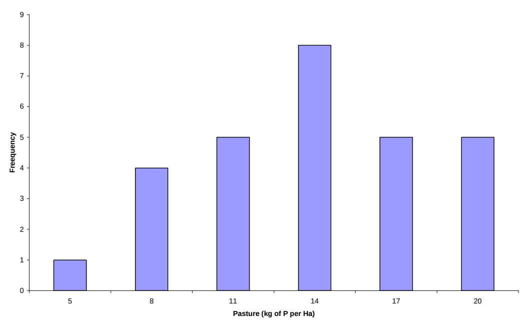
The fertiliser application is across all enterprises however the amount applied may vary for different enterprises depending on the product. Quantity of phosphorus (kg /ha) applied is shown in Table 1.

Table 1. Quantity of phosphorus applied

Pasture		Crop	
Minimum	4.55	Minimum	7.0
Maximum	18.96	Maximum	31.28
Mean	12.61	Mean	19.7



Average Crop P kg/ha



Average Pasture P kg/ha

Figure 3. Distribution of phosphorus application for crop and pasture enterprises.

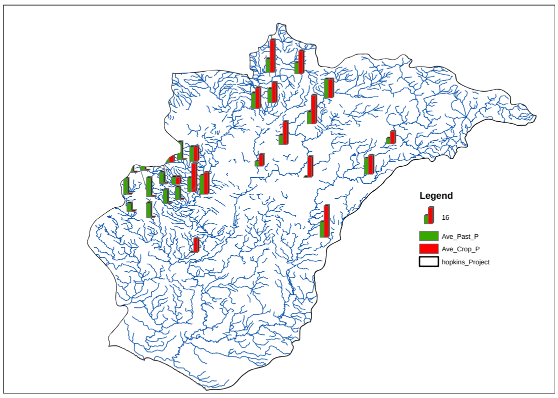


Figure 4: Hopkins River Basin and Phosphorus Use

The survey also indicates that 53 % of the farmers in the project are using phosphorus fertilisers within the optimum range advised by the Department of Primary Industries (13-18 kg P/ha), and further 42% are below the recommended input overall (DPI, 1999). Target soil Olsen P (Ave 15.8) and current soil Olsen P (ranging from 7-18) indicate why farmers are applying more, or less than the recommendations. Higher phosphorus application is being made to specific paddocks to bring the soil Olsen P up to the recommended levels. A low soil Olsen P target may be chosen for areas of native pasture which have a lower phosphorus requirement.

A high percentage (>80%) of farmers are using soil and/or tissue testing to judge how much fertiliser to apply. Research into adoption of new production practices uptake, has shown that farmers who participate in groups (such as the groups that were approached) have a greater uptake of ideas and technology (Trompf and Sale , 2001). This suggests that the farmers participating in this project may not represent the whole farmer population. A common problem faced by researchers, facilitators and extension staff is 'how to reach the average farmer'.

The range of fertilisers used in the district varies from property to property. The range includes Single Super, MAP, DAP, Urea, Sulphate of Ammonia (SOA), Lime, Gypsum, Dolomite, Trace Elements; Cu Mo Zn B, Potash, Pig Manure, Hay booster, Emfert, Goldphos blends, High analysis pasture fertiliser (triple super).

3.4 Timing

Generally the Phosphate fertilisers, lime, potash, gypsum and trace elements (if required) are applied in the late summer to early winter period, with the cropping fertilisers drilled in at sowing. The nitrogen fertilisers are usually applied to crops, hay and fodder crops in winter to early spring, and maybe in a split application.

Decisions on the amount of fertiliser used are influenced by several factors, most importantly, advice from agronomists, the Department of Primary Industries and past experience. Budget, soil tests, seasonal climate and stocking rate also play a role in determining management. 83% of landholders use soil or tissue tests to help determine appropriate fertiliser use. Approximately a third of landholders are considering changes to the current regime.

Contractors are used by 80% of the landholders to spread some or all fertiliser. This affects the ability of the landholders to change timing practices because they are dependant on the availability of the contractor at the optimum time of application. The fertiliser 'Codes of Practice' are followed by 53% of landholders however as there is an education program supported by the fertiliser industry, including most of the fertiliser spreading contractors, it is likely that this percentage is more than that indicated (Melland, 2003). Department of Primary Industry programs, such as the 'Environmental Best Management Program' are raising the awareness of these Codes of Practice amongst landholders (Hunter, 2007).

3.5 Fertiliser costs

Fertiliser costs were estimated to range from 10-30% of the total farm costs per annum (two estimates put the cost of fertiliser at 40-45% of the variable cost). The margin of benefit was estimated by 50% of the participants at between 1.75 and 8 times the input cost. These figures are supported by South West Farm Monitor Group figures of 1:3.8 to 1:8.3 for the margin of benefit, depending on enterprise (Department of Primary Industries, 2007).

3.6 Nutrient Pollution Awareness

A range of answers was given which indicated that 76% of the participants have an acceptable understanding of nutrient pollution and the agricultural practices that contribute to it. Only 10% of participants had observed the detrimental effects of nutrient pollution and a further 10% felt that it was rare, 80% of participants do not view nutrient pollution as relevant to them and their community currently. However 56.6% were concerned with the long term effect of nutrient pollution in the future.

The range of answers given in relation to how they could contribute to solving the problem of nutrient pollution supported the above evidence i.e. that they have a good knowledge of practices that contribute to reducing nutrient pollution.

3.7 Values

27% of participants put a high monetary value on a healthy catchment however this may not reflect the true value of the catchment to the participants as 57% found the question difficult to answer. Only 10% put little value on a healthy catchment.

3.8 Waterways

20% of the property owners have all of their waterways fenced and re-vegetated to at least 10 m from the edge of the water, 17.8% have no waterways fenced, and 46% have somewhere between 5 and 90% of their waterways fenced. This is relevant to a reduction in contribution of particulate phosphorus to the pollution of waterways through erosion of stream banks, presence of a buffer region of vegetation to catch moving soil particles and use of soil phosphorus by vegetation along the waterways. The federal government has been supporting fencing and re-vegetation of waterways for the past 17 years through the Catchment Management Authorities.

4 DISCUSSION: SURVEY AND MODELING

Game theory, which is used extensively in diverse areas of natural science, economics and social/political sciences, was developed early in the last century to provide models of how groups of human beings/ organizations interact and make decisions in a risky/competitive environment. Games are broadly divided into two classes:

- Non-cooperative: each player or group of players is totally antagonistic, i.e. in a conflict situation, to each other. The main objective of non-cooperative games is to find the optimal strategies which players can use to optimise one or more utility functions.
- Cooperative: players are able to form coalitions and utilities are transferable (shared) between members of these coalitions. The main objective here is to understand how cooperation could lead to better distribution of benefits to all players.

This approach in resource modeling is outlined in (Zeephongsekul and Schreider, 2007) in more detail.

The ultimate task of the survey described in the present work is to find ‘what the most plausible player structure is’ in the game proposed and ‘what room there is for potential player coalitions’.

In this case the strategies being explored for players (the farmers) in the cooperative game theory equation are:

- Timing of phosphorus application
- Amount of phosphorus application

Information required for calculating the ‘Payoff Function’ includes:

Production output and value

- Area under production
- Type of ‘crop’
- Phosphorus kg/ha input
- Amount of water available (rainfall)
- Quantity of ‘Crop’ produced
- Revenue per unit of crop
- % Phosphorus absorbed by the crop
- Base soil phosphorus
- Price of phosphorus

Cost factors

- Phosphorus kg/ha input
- Price of phosphorus
- Cost per unit of application
- % phosphorus not absorbed by the crop (runoff)
- Toxicity threshold of phosphorus in waterways
- Environmental impact
- cost per unit application of phosphorus
- Impact of external properties on the player’s property and phosphorus runoff

Equation for payoff equals the value of crop produced minus environmental impact minus impact of other players on our player’s domain.

Value of crop = For each individual farmer and the sum of all his crops

Price* quantity/area*A*(P input* % absorbed+ base P in soil)* Water

Minus Environmental Impact

For each individual farmer and the sum of all his crops

Cost /unit of application*(P input *% runoff-minimum toxicity)*Impact on external players

Minus Impact of other players on our player’s property

$ß_i$* Environmental Impact where $0<ß_i >1$

The information gathered from the farmer groups supplies the equation with the phosphorus use, production enterprises, areas and the amount of rainfall (water available).

For the equation the 'economics of production' are obtained from the South West Farm Monitor Project data. (DPI, 2007). The data has been collected annually for 36 years from farmers in south west Victoria and some of the farmers participating in our project also participate in this group. Figures for the economics of nutrient pollution are to be taken from a comprehensive evaluation of the Glenelg Hopkins catchment undertaken by Read, Sturgess et al, 1999. Other figures will be drawn from past research on phosphorus impact undertaken in the region.

The study group of farmers indicated a good knowledge of the agricultural practices which contribute to nutrient pollution. They are willing to be a part of the process of reducing possible nutrient runoff as they can see the benefit to production, however few regarded nutrient runoff as a current problem in their own catchment.

By raising awareness of the actual status of the region's rivers and the potential impact of landuse practices will highlight the off site benefits.

The survey raises the question of practicality of management change. If over 80% of the farmers are using contractors to spread fertilisers then the ability of manipulating timing in the equation needs to take this into account. It may be possible to split the single phosphorus application into 2 or 3 applications throughout the year. This may reduce the occurrence of application during potentially vulnerable periods (high rainfall events occurring within 4 days of application) and thus reduce runoff. On a practical level availability of the contractor to do this would be necessary and it may also incur additional cost.

5. CONCLUSIONS

The payoff function will indicate the best management practices to be used by each individual farmer in relation to timing and amount of fertiliser used to maximize production and minimise nutrient pollution from their farm. Scheduling of fertiliser application can then be coordinated throughout the group and contractors in the local area can be approached. There should also be benefits to the contractors work schedule. The use of the game theory equation will give the farmers additional knowledge of the best outcomes for production, while also taking the impact on the environment into account.

Future possibilities for the use of game theory and agricultural impact on water quality include management changes to other fertiliser applications (e.g. Nitrogen) and the impact of fencing waterways and re-vegetation to the reduction of nutrient pollution. The information gathered from the survey indicates that more than 80% of farmers are working towards fencing waterways, with 14% having completely fenced waterways. The cost effectiveness of the policy could be examined to reinforce the benefits of the approach however more detailed monitoring of nutrients in waterways would need to be undertaken.

By utilizing information on actual use of fertilizers and farmer attitude to nutrient impact on the environment our research mirrors the actual situation. This research will influence the management decisions made by farmers in the use of fertilisers which ultimately will have an impact on the amount of phosphorus entering streams in the Hopkins river basin.

6. ACKNOWLEDGMENTS

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