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ORIGINAL ARTICLE

Stakeholder engagement in social learning to resolve controversies over land-use change to plantation forestry

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Abstract Rapid land-use change arising from incentives for afforestation has created tensions in rural communities previously dominated by agricultural enterprises. This paper reports on an innovative experiment with social learning that incorporated participatory modelling to resolve community concerns in a case study of plantation forestry in the Upper Clarence catchment of north-eastern NSW Australia. The development of a diagnostic framework helped identify socioeconomic and environmental issues within the community for investigation by a self-selected participatory advisory committee (PAC) representing a diversity of views. Implementation of a social learning exercise offered empathetic and intellectual engagement among PAC members that maintained interest, built confidence, and improved problem-solving capacity while fostering group ownership over decision making. A shared understanding of dynamic landscape problems helped empower participants to collaboratively develop solutions for improved management and operational practices, and cooperate to explore further options for plantation industry development under existing policy guidelines which are presented in this paper. As a result of frank discussions between diverse stakeholders in a mutually respectful learning environment that combined local, scientific and expert knowledge, concerns dissipated and participants developed a more favourable view of plantation forestry activity.

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Introduction

Significant tracks of Australian landscape have undergone rapid land-use change to plantation hardwood forests previously dominated by agricultural livestock and crop production activities (Schirmer et al. 2005; Williams et al. 2008). Social studies have highlighted a diversity of views within rural communities towards the expanding plantation forestry industry, where controversies over socioeconomic and environmental impacts have been documented by Leys and Vanclay (unpublished data), Lochie (2003) and Williams (2008), though difficult to resolve using traditional top–down measures. Brown (2002) highlighted the inherent problems of one of the major intergovernmental policy reforms in Australia through Regional Forest Agreements (RFA) implemented between the years 1995 and 2000 to help overcome community controversies, largely failing due to insufficient engagement with local stakeholders. Research from other developing and developed countries has also shown that the lack of effective mechanisms to resolve social conflicts and ineffective governance have been major constraints to successful plantation forestry development (Nawir and Santoso 2005; Niemela et al. 2005).

In natural resource management, stakeholders are social actors or institutions that have a significant interest in a given set of natural resources, acting a various spatial scales (e.g. local, national, international, private or public), that can affect or be affected by interventions or operational decisions. This paper critiques the role of stakeholder participation for addressing issues of controversy over plantation forestry with a case community through an innovative bottom-up approach to community engagement that involved the application of social learning theory to investigate and help resolve issues causing conflict. Social learning is defined in this study as a group process whereby knowledge is shared and created between stakeholders with diverse experiences and views on natural resource management that are embedded into the learning process, aimed at strengthening the communities capacity to collaboratively manage ecosystems sustainably for human well-being. Social learning can therefore assist in governance of natural resources, a construct shared in research by Connick and Innes (2003), Pahl-Wostl et al. (2007) and Schusler et al. (2003) based on collaborative management and partnership arrangements (Lockwood 2010).

Various tools have been reported in literature for use in social learning processes, and in this study participatory modelling based on system dynamics was evaluated by participants for its effectiveness in exploring issues of controversy over plantation forestry and developing shared understanding. According to Sterman (2000), system dynamics is an interdisciplinary method drawing on cognitive and social psychology to enhance learning and understanding of the behaviour of complex non-linear systems, in particular identifying and helping overcoming defensive routines and resistance thought to have merit for use in this study with the plantation forestry industry. Participatory modelling on the other hand refers to an analytical model building process using simulation software to incorporate participant knowledge and initiate collective problem solving (Brown Gaddis et al. 2009; Standa-Gunda et al. 2003), useful for collating systems data and running alternative management scenarios. Participatory modelling was used in this study based on findings in literature that simulation can assist in cognitive mapping (referred to as representations of mental models by Giupponi et al. 2006) and improve a group's information-processing capacity (Rouwette et al. 2002; Vennix 1999).

The importance in developing a diagnostic framework to operationalise social learning in natural resource management is an emerging discourse to add research rigour to such processes (Brown Gaddis et al. 2009; Leys et al., unpublished data; Lockwood 2010; Lopez-Ridaura et al. 2002; Steyaert and Jiggins 2007), inclusive of trust building early in the process (Armitage et al. 2009; Hahn et al. 2006; Voinov and Brown Gaddis 2008) and participant evaluation (Chess and Purcell 1999; Conley and Moote 2003; McGurk et al. 2006). The purpose of this paper is to provide evidence for the usefulness of social learning in resolving landscape problems through the development, operation, and evaluation of a diagnostic framework by a participatory advisory committee (PAC) investigating sustainable plantation forestry development. Firstly, the reader is provided with a background to plantation forestry expansion in Australia to develop understanding on underlying causes for community controversy, followed by a discussion on the theoretical concepts that were operationalised in the case study to help resolve issues of concern supported by findings from social learning investigations.

Policy scene for afforestation in Australia

The Australian plantation timber industry had been expanding on average 80,000 hectares per year up until the global financial crisis in 2009 (Australian Plantation Timber Industry 2006) driven by Australian government policy to support major expansion in the timber resource by 2020 (MCFFA 1997). Fiscal incentives in support of this policy have been provided through national taxation legislation under Division 394 of the Income Tax Assessment Act 1997 for Managed Investment Scheme (MIS) retail forestry projects (PJCCFS 2009). This incentive was intended to address a gradual decline in public and industrial plantation investment and native forest timber supplies as domestic and export demand for sustainably grown wood and paper products increased (Plantations for Australia 2008).

MIS encompasses a variety of structures based on collective investment in a common enterprise, and forestry MIS refers to plantation forestry projects which may be ready to harvest in 8–25 years (PJCCFS: Parliamentary Joint Committee on Corporations and Financial Services 2009). Under current taxation rulings, investors are entitled to full year-of-expenditure business deductions and a 12-month pre-payment rule dependant on a minimum of 70% direct forestry expenditure in planting, tending and harvesting the trees and transport to mill, and annual costs of the land over the life of the project (Cummine 2008), however excludes costs such as management fees, administration and marketing the scheme (PJCCFS: Parliamentary Joint Committee on Corporations and Financial Services 2009).

An inquiry of MIS schemes in Australia in late 2009 by the Parliamentary Joint Committee on Corporations and Financial Services (PJCCFS: Parliamentary Joint Committee on Corporations and Financial Services 2009) recognised that while there was vigorous debate over whether the continued expansion of Australia's plantation output by 2020 had a sound economic basis, they recommended that an inherent current disincentive to invest in forestry warranted the retention of existing legislative arrangements. The committee noted that the failures of two of Australia's largest companies based on MIS retail forestry (Timbercorp and Great Southern Limited) in 2009 should focus future investors' attention on MIS profitability and as such negate the worst effects of what they describe as indiscriminate capital investment.

Dargusch (2008) reported on perceptions of corporate governance by senior managers for firms operating with forestry MIS in eastern Australia, where MIS structures accounted for approximately 34% of total plantations in Australia (PJCCFS: Parliamentary Joint Committee on Corporations and Financial Services 2009). While Dargusch's research methodology was limited to interviewing only nine male managers from three firms, it did capture an increasing awareness by senior managers that sustainable corporate governance of forestry MIS relied not only on business profitability, however also positive environmental and social outcomes. This included through improved operational organisation that encompassed conservation and eco-efficient behaviour, and support for people.

All Australian states and territories have codes of practice to regulate plantation forestry compliance, with approximately 63% of plantations certified under the Australian Forestry Standard (AFS) and Forest Stewardship Council (FSC) (Plantations for Australia 2008; CPQCPP 2009). Certification aims at ensuring best practice in forestry, regional planning, land use and sustainable natural resource management under national Department of Agriculture, Fisheries and Forestry governance (Australian plantation timber industry 2006) and assists plantation companies use MIS as a vehicle for resource expansion (Mike O'Shea, Forest Enterprises Australia 2008, pers. comm.). This policy structure has provided incentives for plantation expansion that have not been welcomed by most other competing land users, creating situations of conflict and animosity in communities, particularly regarding perceptions of negative environmental and socioeconomic impacts (Leys and Vanclay, unpublished data; Schirmer et al. 2005; Schirmer 2008a, b; Williams 2008; Williams et al. 2003, 2008). Billen et al. (2009) suggests external drivers such as expanding international markets were forcing rural communities to evolve as evidenced by changing rural land bases.

Need for improved community engagement by the plantation forestry industry

The release of a progress report on the Plantations for Australia 2020 vision in 2008 highlighted a broader lack of engagement between commercial forestry companies and communities for addressing environmental and socioeconomic issues (Plantations 2020 vision review 2008). To date, community engagement in Australia has been restricted to the operational level by forest managers, however with limited success reported due to a lack of trust and transparency within communities towards private plantation companies and limited capacity within the industry (Dare et al., unpublished data).

This paper supports the need for new policy discourse, arguing that community engagement should involve a process of social learning to share knowledge and collaboratively explore for new knowledge, skills and behaviours that can help communities adapt and adjust to change. Rolfe (2006) distinguishes adaptation as a function of recovery factors to bounce back from crisis situations or change, as opposed to adjustment which involves the influence of protective factors to maintain functioning. Research by Keen et al. (2005), Mostert et al. (2007), Muro and Jeffrey (2008) and Steyaert and Jiggins (2007) provided evidence for processes of social learning in natural resource management that co-created new knowledge and a shared understanding of complex and uncertain problems, leading to better social outcomes than otherwise possible.

Social learning as a bottom-up approach to community engagement

Social learning has been reported to play a positive role in the transformation of value systems to help communities adapt to external triggers such as policy and climate change (Satake et al. 2007; Steyaert and Jiggins 2007; Walker et al. 2006). A major challenge is to build skills to facilitate social learning situated at the landscape scale that incorporates local actor knowledge, understanding and experience with scientific knowledge that can allow systems to self-organise (Folke et al. 2005). Social learning has been posited as an emerging field for positively altering people's perceptions of ecosystems to change behavioural practice (Lockwood 2010; Walker et al. 2006).

Social interactions are dynamic (Steyaert and Jiggins 2007), and social learning processes can stimulate a growing awareness of the need for concerted action over the complex problems (Frost et al. 2006). This study introduced new concepts in social learning, focusing on intellectual and empathetic engagement of stakeholders in order to maintain interest, build capacity and incorporate existing and new knowledge to enable improved landscape governance. Intellectual engagement refers to the preference of an individual to participate in cognitively demanding activities such as reading, problem solving and abstract thinking (Dellenbach and Zimprich 2008) alternatively referred to as mental modelling (Giupponi et al. 2006). While empathetic engagement refers to the transfer of affect through knowing and feeling another person's emotions or cognitive thoughts, and responding compassionately (Gruen 2009).

There have been limited reports on strengths and weaknesses of social learning processes for achieving robust understanding to support wider applications (Leys et al., unpublished data; McGurk et al. 2006). McGurk et al. (2006) reported on weaknesses limiting success of social learning activities in forest management and included lack of accountability, deficient coordination, ambiguous decision-making processes, and inadequate opportunities for Aboriginal involvement, poor attendance, and lack of broader community involvement. Strengths reported were information sharing and improved communication, relationship building, influence of operational and site-specific decisions, and conflict management. Participatory processes were found to reduce historical conflict between actors, providing a neutral atmosphere for discussions over water pollution issues in the USA which had previously been divisive (Brown Gaddis et al. 2009). This paper contributes to the literature through reporting on strengths and weaknesses of social learning on plantation forestry dynamics through a participant-based evaluation.

Participatory modelling as a tool in social learning

Participatory modelling (PM) has been posited as a collective of innovative tools that incorporates local stakeholders, the public and decision makers into an analytical modelling process to support decisions involving complex natural resource management problems (Giupponi et al. 2006, 2008; Voinov and Brown Gaddis 2008) and in this study is embedded into the social learning process (Pahl-Wostl et al. 2007). It uses an action research methodology (Dick 1990) to allow iterative and reflexive responses when exploring innovative solutions for dynamic socio-ecological problems (Prabhu et al. 2003; Vanclay et al. 2006). The level of intervention however is uncertain and dynamic according to Steyaert and Jiggins (2007), being dependent on understanding local contexts of changing values and stakes interacting with local history and culture, and therefore requires methodological flexibility while maintaining rigour.

Some of the risk can be managed through the development of context-specific diagnostic frameworks (DF) to help tailor the learning process to local community needs (Brown Gaddis et al. 2009; Leys et al., unpublished data; Steyaert and Jiggins 2007). There have been few applications of PM processes reported in literature, and there remains a need for more robust evaluations to understand the merits of such processes. Visual simulation software programs that have been applied to support decision making in PM include Simile (Vanclay et al. 2006) and mDSS (Giupponi et al. 2006) to record systems and causal linkages (feedback loops) and data input on stock and flows to run alternative management scenarios. Significant research contributions in this growing field are reported by d'Aquino et al. (2002), Prabhu et al. (2003), Standa-Gunda et al. (2003), Giupponi et al. (2006, 2008), Vanclay et al. (2006), Voinov and Brown Gaddis (2008) and Brown Gaddis et al. (2009). This paper contributes further to the literature through an evaluation of the effectiveness of PM situated in a broader process of social learning.

Methodology

The diagnostic framework

The diagnostic framework developed incorporated both qualitative and quantitative social research methods (Fig. 1) to investigate plantation forestry dynamics in a case study of the Upper Clarence catchment of north-eastern NSW, Australia. It highlights the steps involved in the scoping of a case study region, and engaging and mobilising stakeholders into the social learning process.

Plantation forestry estate in the Upper Clarence catchment

The Upper Clarence catchment covers 690,500 hectares (Fig. 2), and has a sub-tropical climate and annual average rainfall of 1,100 mm/year. In March 2009, 4.0% of this land area (27,400 ha) was under hardwood plantation forest and 0.6% (4,230 ha) under softwood plantation (M-C Pelletier, Hurford Hardwoods, pers. comm. 2009). The softwood plantation estate was 100% public State Forest NSW tenure, compared to the hardwood plantation estate with majority ownership and operation by private investment companies. These private investment companies were either wholly or partially dependent on MIS retail forestry investments for generating capital (R. Stanford, Forest Enterprises Australia, pers. comm. 2009).

Gauging importance of landscape scale plantation forestry controversies

Public meetings were held in the case study region to identify issues of controversy within the community over expansion of the plantation hardwood industry and gauge the relative importance of issues using a democratic voting card system for follow-up with an experimental social learning study. An independent professional facilitator was employed to convene and mediate these public meetings to eliminate potential for bias and ensure there was equal opportunity for all participants to express views. The major

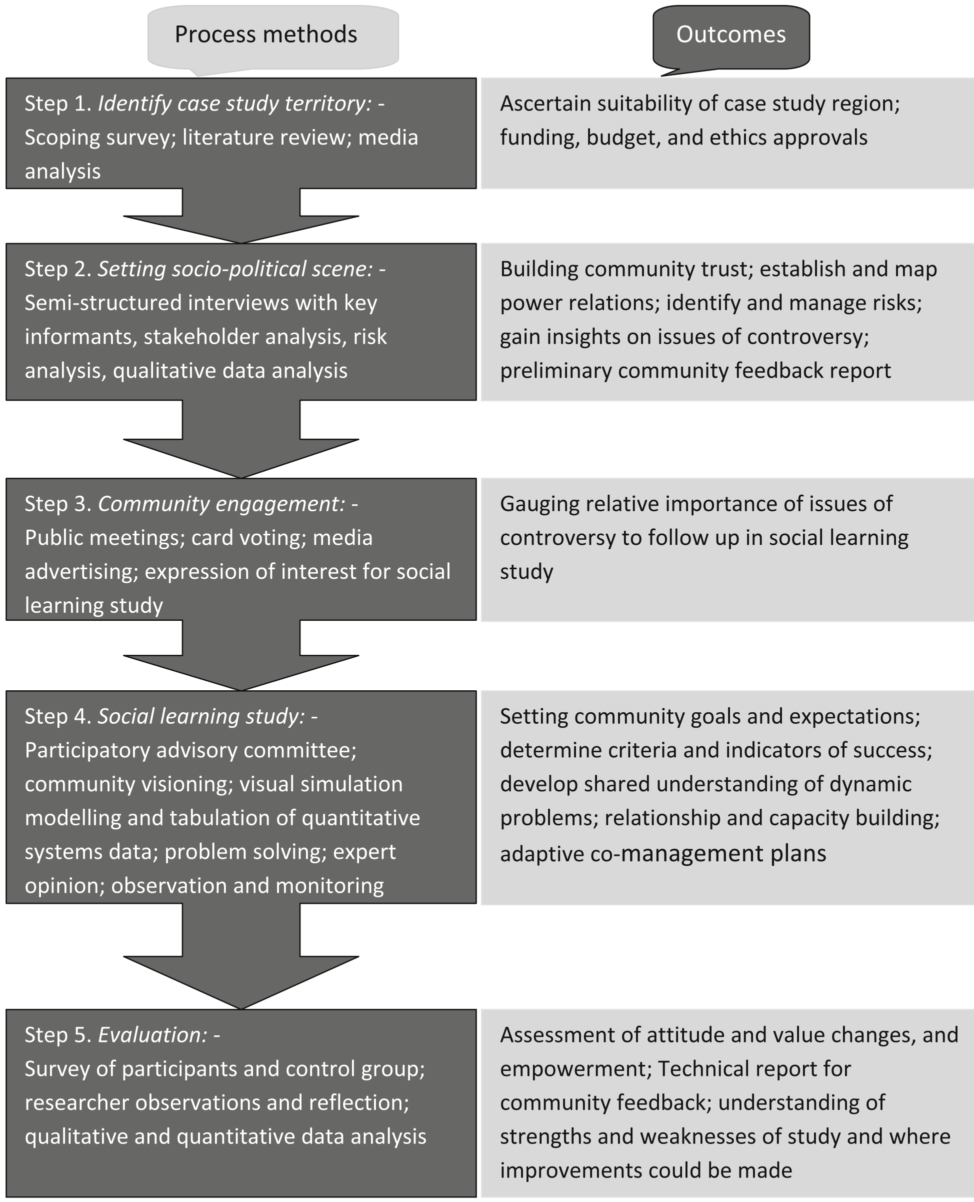

Fig. 1 Diagnostic framework used to implement social learning study of plantation forestry

issues identified were the need for socio-economic benefits to local communities, community consultation and information sharing, improved collaboration between agricultural producers and the plantation industry to allow better property planning, better fire management planning and health impacts from aerially sprayed pesticides (Further information on the process can be found at Leys et al., unpublished data).

During the public meetings, an expression of interest was made to form a participatory advisory committee (PAC). Twelve (12) people volunteered and represented a wide range of views in the community towards plantation forestry. They agreed to meet once a month on average, a process which continued for a period of 8 months during 2009. PAC members worked collaboratively to determine which issues were best addressed through a participatory modelling exercise and in which order. Fire management was addressed first, with participants contributing data and helping collect further data. Expert speakers were invited to fill knowledge gaps on fire planning; however, floods during the study period (media release: ABC 2009) reversed the order of preference for modelling. Pesticide issues were then explored and then socioeconomic impacts, with the results from the social learning exercise and the shared knowledge that was developed presented within this paper. Changes in attitudes and power and influence were monitored throughout the study using observational documentation and participant surveys.

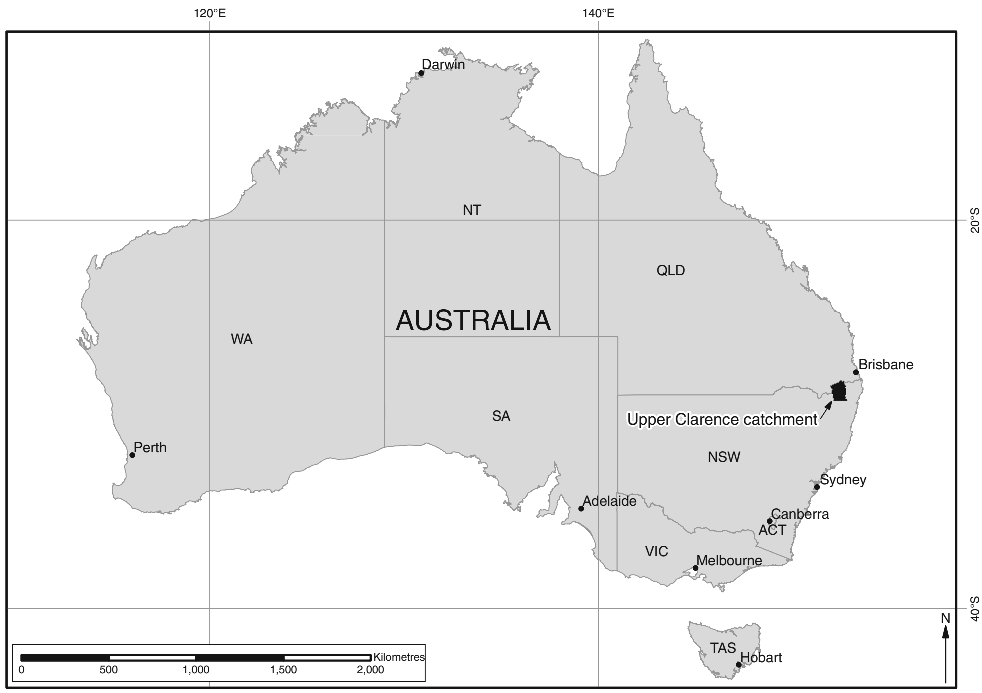

Fig. 2 Location map of the sub-tropical Upper Clarence catchment in north-eastern NSW, Australia (Map produced by Greg Luker, GIS Lab SCU, 1/12/2009)

Results

Fire management in plantation forestry

Several participants were concerned that plantation forests posed a significant fire threat to local villages and biodiversity conservation, particularly as plantations had been established on village boundaries after being authorised at the state government level in NSW with no local government input, an area of policy that participants felt needed changing. Expert speakers contributed knowledge to the PAC on fire management from the various forestry jurisdictions (state, national and private), and it was decided that collaborative fire management plans were needed to address landscape level fire threats. A group was formed between the rural fire service and local plantation forestry companies and other forest tenures outside of the PAC to develop improved property maps with fire trails and watering points as well as fire response plans that went beyond the limitations of this study. However, this initiative alleviated fears of PAC members that the issue was being effectively addressed.

The PAC discussed the positive role of fire, as well as fire threats, in the landscape. According to Lindenmayer and Hobbs (2004) and Lindenmayer et al. (2006), fire management for biodiversity conservation at the landscape-level requires use of variable prescribed fires to emulate natural disturbances, typical of Eucalypt forests in Australia to create a range of conditions or heterogeneity. They suggest that while fire may create unsuitable habitats in one area for a given species, there should be other areas the species can survive. In particular, patches of retained and riparian vegetation in plantation forests should be protected together with watering points and open grazing areas that could potentially increase the diversity and populations of fauna species (Lindenmayer and Hobbs 2004).

Socio-economic impacts of plantation forestry

Investigations into socioeconomic impacts of an expanding plantation forestry industry took many avenues to establish an evidence-based understanding of the dynamics involved. Initially, the simulation modelling software ‘Simile’[1] was used as a tool to conceptually map systems and relationships, and then quantitative data was added by the research modeller and alternative management scenarios explored. Participants did not engage fully with the simulation software due to a lack of technical skills, nor did they choose to learn the program when the opportunity was provided. Instead flip charts, excel spreadsheets and PowerPoint slides proved more effective for graphically presenting data due to participant program familiarity.

[1] Simile is a visual modelling environment supported by computer software. Refer to www.simulistics.com

Changes to demographics

Demographical changes were initially examined that showed results contrary to earlier perceptions among the wider community that rural populations were declining in response to plantation forestry expansion (Leys and Vanclay, unpublished data). Instead populations of the all the local towns and villages except one increased since the last census period, increasing from 2,894 in year 2001 to 3,412 in year 2006 in the Upper Clarence catchment (Source: ABS Census 2009). In regard to occupancy of residences on properties bought by plantation companies and Forests NSW, findings again were contrary to the widely held perception that plantation dwellings were being left vacant. Data examined for all properties purchased by private plantation forestry companies and Forests NSW showed positive impacts on residential occupancy, with a significant increase in permanent residents and school-aged children (Data provided by R. Stanford, PAC member, FEA representative, 2009).

Table 1 illustrates the changes in occupancy for all dwellings on properties after purchase for plantation establishment. Although there was an overall decrease in owner-occupied residences from 66 to 43%, there was an overall increase in full-time occupancy (owner–occupied and full time renters) from 74 to 82%. Of the original 8% of full-time rented residences, 5% had been occupied by farm managers and workers. After purchase, a decreased utilization was reported for this category of tenants. Properties with residences that previously had absentee owners (labelled as occupied part time in Table 1; used as weekenders) had been either subdivided and purchased by new owner occupiers or were now rented out full time; further evidence of an increase in overall occupancy of plantation residences.

Viability of major land use enterprises in the catchment

To ascertain the viability and profitability of plantation forestry, the PAC found it justifiable to make comparisons to other land uses within the catchment. Profitability of beef cattle and the two major crops maize and soybeans were found to be marginal, with fluctuations in grain prices sometimes resulting in negative returns. For farmers, leasing part of their less productive agricultural land to plantation companies was found to be highly attractive due to the reliability of guaranteed annual lease payments ranging from $200 to 230/ha compared to gross margins of other enterprises (Table 2). One disincentive mentioned by a couple of participants was the long contractual tenure of forestry leases ranging from 15 to 20 years.

However, while local plantation companies sought fertile soils for leasing or purchasing, many cropping areas on river flats were not suitable for timber production due to the high incidence of frost. The majority of PAC members believed it was important to preserve a balance between agriculture and forestry within the catchment. Participants favouring a leasing arrangement on the less agriculturally productive parts of properties which could provide an additional source of income to farmers and help maintain local populations and social networks. It was found through modelling that whole farm profitability could be increased substantially when partial forestry leases were combined with traditional beef cattle grazing and cropping. Further, income could be gained from reintroducing beef cattle grazing once plantations were established at around 18 months from planting. For a property scenario of 522 hectares, it was shown that by leasing 200 hectares of this to a plantation company and the balance remaining under unimproved breeder weaner production (90 breeders) that whole farm profits could be increased by 40% or approximately $8,500 (Aus$) per annum.

Timber processing and value adding opportunities

While individual forestry leases could provide positive financial rewards to farmers, a more major landscape concern was the need for a processing facility in one of the nearby regional centres for creating employment opportunities and value adding to the timber estate that would

Table 1 Change to types of occupancy for all residences on plantation properties within the Upper Clarence catchment after purchase by private plantation companies and Forests NSW (Compiled by A. Leys and J. Vanclay from data provided by Rod Stanford of FEA, PAC member, June 2009)

	After					Total %
	Owner occupied	Rented occupied full time	Occupied part time	Vacant	Derelict or removed	
Before						
Owner occupied	40	13	3	3	7	66
Rented occupied full time		8				8
Occupied part time	3	10				13
Vacant		8				8
Derelict or removed					5	5
Totals %	43	39	3	3	12	100

Table 2 Comparison of gross margins for the major land-use enterprises in the Upper Clarence catchment (2009)

Enterprise	Average grain yield (t/ha)	DSE livestock rating (DSE)	Livestock carrying capacity (DSE/ha)	Average grain price ($/t)	Average cattle price (c/kg live)	Gross margin ($/ha)
Hardwood plantation forestry lease annuity	n/a	n/a	n/a	n/a	n/a	200-230[a]
Beef weaners (native pasture)	n/a	10.14[b]	4.0[b]	n/a	158[b]	60[b]
Beef weaners (improved pasture)	n/a	13.82[b]	8.0[b]	n/a	232[b]	134[b]
Maize (minimum-till)	6.5[c]	n/a	n/a	290[c,d]	n/a	417[c,d]
Soybean (minimum-till)	2.6[c]	n/a	n/a	500[c,d]	n/a	384[c,d]

[a] Mr R. Stanford PAC member, local forester, grazier and casual employee of Forest Enterprises Australia (FEA); November 2009 market price range for leasing property by FEA in Upper Clarence

[b] Department of Industry and Investment NSW; livestock data sheets for North Coast NSW

[c] Mr B. Clarke, Casino District Agronomist, Department of Industry and Investment NSW; average crop yields and grain prices for Upper Clarence

[d] Mr M. Smith PAC member, local farmer and grazier, and agricultural service contractor; grain prices are for on farm after cartage costs deducted

ensure long-term industry viability. According to plantation representatives on the PAC, a processing plant was planned for development within the next 3 years. Currently, many operational jobs in the plantation forestry industry were insecure, particularly for planting and machinery contractors in response to the global financial crisis of 2009 and collapse of major plantation companies based on forestry MIS. Through the use of modelling, the future viability and sustainability of the plantation forestry industry in the catchment was found to be highly dependent on continued growth of the estate to ensure timber volumes were available to support a processing mill and value adding manufacturing opportunities like potential biodiesel production from waste timber after silvicultural thinning and mill processing.

Impacts on local businesses

All the local shopfront businesses were provided with a business survey in the village of Woodenbong, the largest urban area in the catchment, upon recommendation from the PAC to collect further socio-economic data. This resulted in a 93% return rate (thirteen out of fourteen) and included the following businesses; pharmacy, arts and craft shops, hotel, bank, post office, machinery contractors and earthmoving, hardware stores, supermarket, machinery engineers and butcher. Due to the high return rate, the results were seen to be representative of the business community in the catchment.

The majority of businesses (62%) were found to have been operating locally for 10 or more years, compared to 23% operating for less than 3 years. Customer volume and volume of sales for the previous 12 months and 5-year periods were found to vary depending on the type of business, however had declined on average for the proportion attributed to plantation forestry customers (who had the majority of their income derived from direct employment with local plantation companies) over the past 12 months. Thirty-nine per cent of businesses reported a decrease in sales and services to plantation customers, while 23% reported no change, compared to 15% reporting an increase to these customers (Fig. 3). Service, food and maintenance businesses reported overall increases in sale volumes suggested to be attributed to a change in customer base, particularly new settlers moving to town that were renovating homes. Other businesses with non-essential goods and services reported a decline in customer volumes and sales.

An important finding from analysis of the business survey was that there was not a significant correlation between the volume of sales and services to plantation companies and overall change in business profitability ($r = 0.514$, $P = 0.129$, $N = 13$; not sig. diff.). This was contrary to previous findings in semi-structured interviews whereby some participants believed a decrease in trade from plantation forestry customers was having a negative impact on local business profitability (Leys and Vanclay, unpublished data). For many businesses where trade to plantation customers declined, business profits either remained unchanged or increased. These findings suggest that plantation companies were not major customers of local businesses, a finding consistent with Schirmer et al. (2005) and Williams (2008) from other plantation communities in Australia.

For the 12-month period October 2008–2009, 31% of businesses reported a decline in business profits compared to 23% over the previous 5-year period, suggesting the past 12 months have been difficult financially for several businesses (Fig. 3). At the same time, 31% of businesses reported an increase in profits over the previous 12 months. Machinery contractors reported large declines in business which they attributed to the financial crisis and drying up of

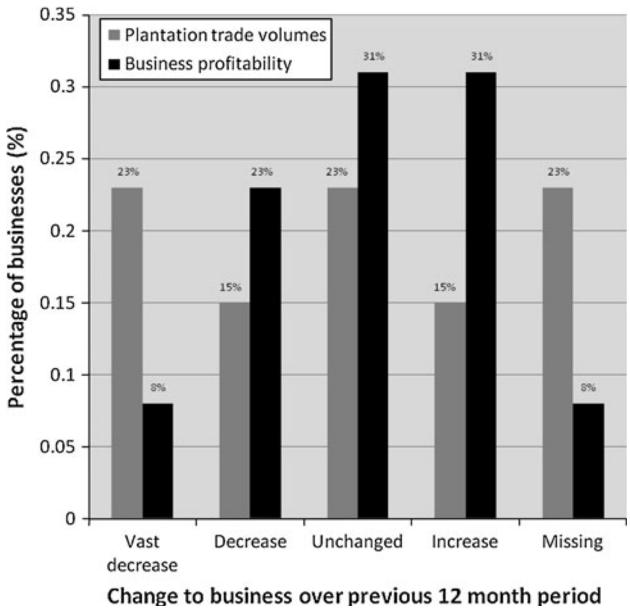

Fig. 3 Change in trade volume to plantation forestry customers and to total business profits for Woodenbong shopfront businesses over previous 12-month period (October 2008-October 2009). $N = 13$

plantation work, with employees having to be put off and machinery sold. Maintenance of fire breaks and fertilizer topdressing were two operations reported as being held off by plantation companies during difficult financial times.

Pesticide impacts on local ecosystems

The PAC found it useful to document the most commonly used pesticide programs on a per hectare basis and across the major land uses in the catchment while investigating impacts of pesticides for fair comparison. This paper however focuses on findings from the plantation forestry industry. Participants contributed data on pesticides rates and frequencies based on their own local knowledge and experience. New knowledge was introduced through research literature, government and NGO reports, and media releases for review and deliberation by the PAC. Expert opinion was also sought to fill knowledge gaps deemed important to participants and as a source of new knowledge. The PAC was actively involved with interpretation of the data and in producing recommendations for improvements in pesticide practice. Pesticide data was collated into tables for visual presentation for PAC deliberation.

Properties of plantation forestry pesticides

The octanol–water partition coefficients (log Kow) shown in the Table 3 indicate how chemicals are distributed at equilibrium between organic (octanol) and aqueous (water) phases. This coefficient is commonly used to predict the environmental fate of organic chemicals including pesticides (Stenersen 2004). The higher the coefficient, the greater the likelihood for the chemical to be partitioned to organic phases, suggesting that the chemical will tend to adhere to organic matter in the soil (organocolloids), and may also indicate a tendency to accumulate in lipids (Copolovici and Niinemets 2005; Kah and Brown 2008). Reports in literature suggest pesticides with log Kow values between 4 and 8 have the potential to bioaccumulate in organisms; however, bioaccumulation is also affected by the molecular weight of compounds. Compounds greater than 600 units weight or 100 g/mol have been found less able to enter animal cells (FIMBAP 2007; Kah and Brown 2008; Rodriguez-Cruz et al. 2006; Stenersen 2004; Tomlin 2006).

Attitudes towards pesticide use

A broad spectrum of attitudes towards pesticide use was present within the PAC, with some members favouring restricted use and others fully supporting pesticide use to maintain productivity and boost returns. Insect damage to commercial stands of *Eucalyptus dunnii* from the psyllid insect *Creiis lituratus* and various Chysomelid beetle species including *Chrysophtharta sp*., *Paropsisterna sp.* and *Paropsis sp*. presented challenges to plantation foresters who believed chemical control was their only option through aerially sprayed insecticides Rogor and Factac Duo (details on active ingredients in Table 3). The woody weed *Lantana camara* and cat's claw creeper *Macfadyena unguis-cati* were claimed to be highly invasive and requiring herbicide control.

Some of the local participants in the study were organic farmers and strongly against the use of aerially sprayed pesticides that could drift onto their properties and contaminate produce and water supplies. Participants representing the Environmental group of stakeholders on the PAC were concerned there was no regulatory compliance regarding use of pesticides in the catchment and believed this was an area that needed improvement at the local and state government level.

Pesticide eco-toxicology risk indicator

A pesticide risk indicator was applied to pesticides based on chemical rates and frequencies most commonly used in plantation hardwood forestry (Table 3). From a modelling exercise comparing pesticide use in all the major land uses, it was found that pesticide usage in hardwood plantation forestry changed dramatically in the years after establishment, with the highest pesticide dependency prior to

Table 3 Pesticide application rates used in hardwood plantation forestry in the Upper Clarence catchment and corresponding material data (Compiled by A. Leys from data provided by PAC members and sources: Extonet 2009; FSC-IC 2009; QDPI Infopest 2009; APVMA 2009; MSDA 2009; Tomkins 2004; Eddleston et al. 2005; Jenkin and Tomkins 2006; Copolovici and Niinemets 2005; Johnson et al. 2007; Tomlin 2006; LeBaron et al. 2008; Yordanova et al. 2009)

Pesticide	Rate of application (L or kg/ha)	Active ingredient/s (a.i. name)	Frequency of application (no./year)	Ecosystem load[c] (grams a.i./ha/ appl'n)	n-octanol : water (log Kow)	Half-life (days)	Eco-toxicity risk indicator (X–XXX)[b]
(a) Herbicides							
Simazine 900	5.5 kg/ha	Simazine	1.5/15[a]	4,500	1.960	60	X
Glyphosate	2.0 L/ha	Glyphosate isopropylamine	5.0/15	900	−3.000	47	–
Verdict	0.15 L/ha	Haloxy fop-R-methyl ester	0.5/15[a]	86	3.320	55	–
		Diethylene glycol mono ethyl ether	0.5/15[a]	77	−0.920	6	–
Lontrel	0.1 L/ha	Clopyralid TIPA salt-aminopyralid	0.5/15[a]	51	−2.870	40	–
(b) Insecticides							
Rogor	0.8 L/ha	Dimethoate	4.0/3	240	0.699	7–20	X
		Cyclohexanone	4.0/3	450	0.810	5	–
Fastac Duo	0.5 L/ha	Alpha-cypermethrin	2.0/3	50	6.600	30	XXX
		Xylene	2.0/3	375	4.300	7	–

[a] Simazine was additionally applied on 50% of the plantation area as a follow up post-planting herbicide application together with Verdict and Lontrel for residual weed control, accounting for the 1.5 and 0.5 applications respectively over the average 15-year production cycle

[b] A rating for potential eco-toxicity of the commonly used pesticides was applied using a scale of X low risk to XXX high risk,—otherwise not considered a significant risk under routine applications

[c] Ecosystem load refers to a quantitative measure of the amount of active ingredient applied to the environment per unit area at a particular point in time

planting for residual weed control and during early establishment to reduce competitive pressure from weeds. Further, insecticide usage in plantation forestry was specific to Eucalypt species, with *E. dunnii* being particularly susceptible to insect attack and in need of regular monitoring for selective spraying to reduce pest outbreaks that could potentially devastate plantations. During the course of the study, representatives from the plantation forestry industry acknowledged that *E. dunnii* had a high reliance on pesticides and were now aiming to plant species less susceptible to insect attack including *E. saligna* (Sydney blue gum) and *Corymbia maculata* (spotted gum). *E.cloeziana* (Gympie messmate) was another species recommended through expert opinion, although it's lower frost tolerance would restrict site suitability.

Pesticide footprint of the plantation forestry industry

Tabulating pesticide footprints for all the major land uses in the catchment highlighted the lower overall reliance on pesticides in hardwood planation forestry compared to annual crops including maize and soybeans when active ingredients were standardised over an average 15-year production cycle in the catchment. An interesting finding of this study was in the use of the S–triazine residual herbicides (LeBaron et al. 2008; Walker and Blacklow 1994), found to have approximately ten times higher footprint in maize cropping through the use of Atrazine compared to use of Simazine in hardwood plantations. While the log Kow levels (ratio of octanol:water solubility) of both these triazine herbicides were found to be less than 4 (atrazine log Kow = 2.34 and simazine log Kow = 1.96) and therefore not expected to bioaccumulate in animals, some scientific literature has claimed there are potential acute and sub lethal toxic impacts as endocrine disruptors on mammals and amphibians if not used in accordance with the regulatory label (Fan et al. 2007; Hodgson and Levi 1996; Horrigan et al. 2002).

Pesticide recommendations by the PAC

In Australia, the S-Triazine chemicals are not listed for use in drinking water catchments under National registration of the Australian Pesticides and Veterinary Medicines Authority (APVMA) and as such no levels should be detectable in drinking water supplies. Each state and territory government in Australia have been given the responsibility for monitoring pesticide safety. In NSW, surveillance of rural drinking water quality is under the jurisdiction of local councils, while not having a statutory requirement to monitor water quality, the legislation does require closure of drinking water supplies if they are found unfit for drinking under the Public Health Act of 1991 and if anyone is found polluting public water supplies under the Local Government Act of 1993 (NSW Public Health 1994). Further information on guidelines for use of herbicides around water is provided by Ainsworth and Bowcher (2005) and in plantations by Tomkins (2004) and Jenkin and Tomkins (2006).

In addressing the community concern regarding potential compromise to drinking water standards and adverse impacts on wildlife in local ecosystems from the use of aerially sprayed pesticides in the catchment, the synthetic pyrethroid insecticide Fast-tac Duo in hardwood plantations was considered to present the greatest risk (Yordanova et al. 2009). The relatively long soil half-life (30 days) and lipophilic nature (log Kow of 6.6) of its active ingredient alpha-cypermethrin gives it potential to bioaccumulate, illustrated using an ecotoxicology risk indicator in Table 3. For this reason, the PAC recommended restricted use of this chemical and only under extreme caution, potentially phasing its use out all together, with softer (less toxic) alternatives provided in Phillips (2007).

This finding was contrary to previous public perceptions that the insecticide Rogor (active ingredient dimethoate) used in plantations posed the most risk to human and ecosystem health (Leys and Vanclay, unpublished data). Dimethoate was found to have a relatively short half-life, varying from 7 to 20 days in soil with a low log Kow value of 0.699 (Table 3) suggesting it is not expected to bioaccumulate. The high water solubility of dimethoate (Johnson et al. 2007) when applied under a sub-topical rainfall pattern provides argument for significant dilution of this pesticide in the environment that should not present significant health risks at rates and frequencies (Margni et al. 2002) used by the plantation forestry industry. However due to the nature of organophosphorus pesticides for acute toxicity, it should be used with caution and further toxicology investigations undertaken (Davies et al. 2008; Eddleston et al. 2005).The investigation further highlighted that the fate of pesticides was highly dependent on the level of runoff and temperature subsequent to application, as well as site characteristics in slope, soil texture and organic matter levels. As such, it was recommended that all users of chemicals considered to have potential ecotoxicology risks not only use them with caution, however the local council monitor for contamination of drinking water supplies, particularly in times of consistent moderate rainfall around planting time to help alleviate fears of local residents. A sophisticated model has been developed by the CSIRO in South Australia called the Pesticide Impact Rating Index (PIRI; Kookana et al. 2005) which was recommended for modification for monitoring likely contamination of surface and ground water supplies by local councils. Further research is recommended in this area.

Evaluating changes in attitudes of PAC members and effectiveness of social learning strategies

Throughout the PAC process, attitudes among participants were monitored, and a general growing awareness and understanding of plantation forestry management and operational practice led to a gradual increase in support for the industry and less controversy. A final evaluation of the study by PAC members provided empirical evidence for a shift in attitudes towards the plantation forestry industry (mean 2.75, SD 0.71; equiv. to moderate improvement). Additional comments by participants included: that over the years they had seen “much improvement since the early days”, some preferring “corporate owned rather than public (state) owned plantations” suggesting they were “better managed and pay council rates”.

Analysis of the final evaluation survey highlighted areas participants felt were most effective in the learning process for reducing controversy (Fig. 4). They were particularly satisfied with the social learning process, finding it fair to contribute equally to dialogue and an interesting process, highly valuing facilitating researchers input and expert opinion and local knowledge. Time efficiency was a factor for some who suggested that meetings went too long, generally lasting 3.5–4 h each, although they always stayed till closure. The PAC rated the findings of the study as helpful in terms of how informative and useful they would be to the broader community. The visual modelling environment ‘Simile’ also rated highly for usefulness in social learning, however deemed most effective as a tool for researchers due to the high level of technical expertise required to run the program.

The analysis also found 75% of PAC members felt the recent collapse of private plantation companies based on MIS contributed to a more negative image of the industry. While 75% supported private leasing of properties by plantation companies, 100% supported family farms with agro-forestry enterprises. Eighty-eight per cent supported mixed species plantations and only 38% supported monoculture timber plantations, which was not unexpected due to discussions on negative impacts of monoculture on biodiversity in the region.

Discussion

Evaluation of a case study in social learning provided evidence of effective community engagement between the plantation forestry industry and a rural community where controversies over complex natural resource management issues were resolved. The study used empathetic and intellectual engagement between stakeholders for developing a shared understanding of dynamic problems and the

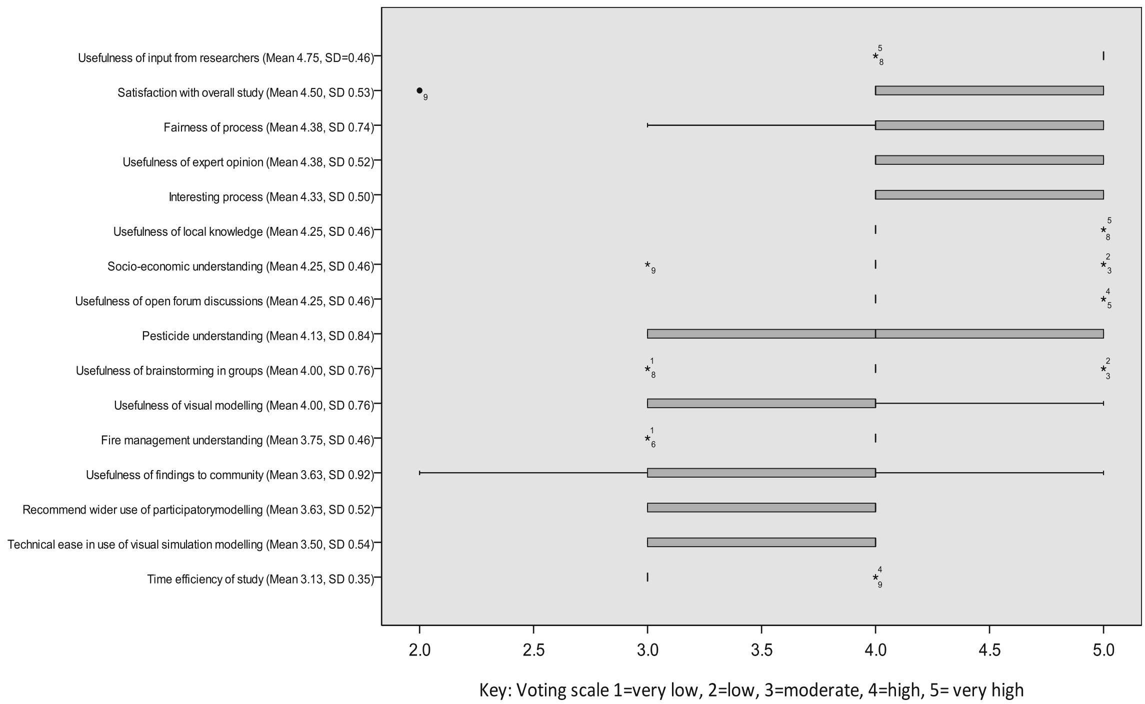

Fig. 4 Evaluation of social learning study by members of the Participatory Advisory Committee using box plots. $N = 11$. *Note:* Similar numbers shown on *box plots* represent the same participant throughout the evaluation

development of collaborative solutions for improving socio-economic and environmental outcomes under existing forestry policy. One of the strengths in the study was the fairness of stakeholders to contribute equally to dialogue. This was fostered through the employment of an independent facilitator who used strategies to minimise power differentials between stakeholders and eliminate risk of creating a biased agenda (Muro and Jeffrey 2008) or a situation of civic elitism by particular self-interest groups (Parkins and Sinclair 2009).

While participatory modelling in its purely analytical form (Voinov and Brown Gaddis 2008) provided a useful entry point for researchers to initiate discussions, it became evident that participants found its application limited due to the high level of technical expertise required to run the 'Simile' program used in this study. A variety of alternative strategies were used which helped motivate and foster engagement with technical competence, consistent with findings of Giupponi et al. (2006, 2008), Mostert et al. (2007) and Pahl-Wostl et al. (2007) including open discussion with local actors, scientific researchers, and invited expert speakers to develop an improved understanding of problems, build confidence and capacity for collective decision making.

The use of social research methods to monitor and gauge changes in attitudes as social learning progressed, identified the creation of new knowledge as an important criteria for alleviating fears and reducing controversy within the community through providing empirical evidence to debate perceptions found earlier in the study (Leys and Vanclay, unpublished data), consistent with the merits of social learning processes reported by Steyaert and Jiggins (2007) and Walker et al. (2006). Another strength identified was the ability of the PAC members including the research team to develop trust and establish alliances. This was demonstrated through the continued attendance by all members at regular evening meetings over the 8-month study period. However, the lack of engagement by marginalised groups including the Indigenous Aboriginal community was of concern to some PAC members, although consistent with findings by McGurk et al. (2006) and McDermott and Schreckenberg (2009) suggesting the need for further research in this area.

The major socioeconomic findings from the social learning process included potential for increasing regional employment opportunities through the development of a processing mill. Future expansion of plantation forestry was found to be most socially acceptable through partial property leasing of private farms to maintain existing social structures and demographics and provide economic benefits to local farmers. Alternately, farmers wanting to retire or move from the region found it very viable to sell out due to the good prices being offered by plantation companies.

Major environmental views expressed by the PAC included promoting future use of the plantation species *Eucalyptus saligna*, *Corymbia maculata* and *E. cloeziana* that offer improved pest and disease resistance and timber properties compared to the most prevalent species *E. dunnii.* Further research on biodiversity conservation was recommended as it was considered to be compromised by an increasing area of the catchment under monoculture plantation and the removal of hollow remnant trees for wildlife habitat. It was established that effective fire management planning could not be done in isolation; rather there was a need for an integrated approach between different land-managers and fire authorities. The need was recognised for improvements to monitoring known pesticides for potential contamination of waterways, drinking supplies and groundwater by local government. This was suggested to eliminate concerns and increase confidence of local residents that local water quality standards were being met. Adaptive co-management involved an agreement to move towards the use of softer pesticides by all land users. During this study, a local expert group formed outside the PAC to address a shortfall in legislation regarding management prescriptions for retained vegetation in plantations (Baker et al. 2009).

The findings of this study emphasised the local nature of problematic NRM issues, and the importance of understanding the socio-political dynamics of stakeholders early in the diagnostic process to maximise engagement in social learning. Prager and Freese (2009) suggest support from a diverse group of stakeholders enhances legitimacy of the study and the likely acceptance of recommendations within the community. The recommendation by the PAC for integrated collaborative management particularly in the areas of fire management, water quality monitoring, and biodiversity conservation, support a view put forward by Brondizio et al. (2009) that local networks are embedded in larger socio-ecological systems that need to be considered for effective governance of natural resources. This study supports adaptive co-management theory proposed by Walker et al. (2006) where diverse stakeholder groups contribute to the transformation process of local socio-ecological systems and the operationalisation of adaptive governance reported by Folke et al. (2005), an area increasingly recognised as important in the face of a global resource crises and climate change, and associated value changes in society.

Conclusions

The development of a robust diagnostic framework supported the effective implementation of a process of social learning supported by participatory modelling to explore controversial issues over plantation forestry expansion in Australia. The process offered a multi-disciplinary platform linking research and community, and built capacity for collaborative problem solving between diverse stakeholders through knowledge generation, confidence and relationship building, and the development of group learning skills. Individual attitudes changed throughout the process highlighting the dynamic nature of social interaction and role of cognitive learning in resolving controversy. For these reasons, social learning processes could be used more widely in rural communities where there is conflict over natural resource management.

Limitations were found for the use participatory modelling as a tool of social learning due to the technical skills required to run the visual modelling software 'Simile' used in this study. Therefore, participatory modelling would be most useful when working with community groups with high motivation to learn the software or limited to use as a tool by research modellers embedded in broader processes of social learning. In conclusion, social learning can provide a mechanism for intellectual and empathetic engagement of stakeholders. It can assist in eliciting local and expert knowledge to contribute to the improved management of natural resources, supporting the movement towards participatory planning and decision making in environmental legislation and conflict resolution.

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