Reducing wildfire risk in water supply catchments using payments for ecosystem services

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Abstract In New South Wales (NSW), Australia, local combinations of sclerophyllous vegetation dominated by *Eucalyptus* species, rapid fuel accumulation, terrain and weather can result in a high probability of uncontrollable wildfires. For example, in December 2001 and January 2002 the "Black Christmas" bushfires burned 733 342 ha of forest, including 225 000 ha within the Sydney water supply catchments. Evidence from several studies in NSW indicates that the effects of wildfires pose an unacceptable risk to water supplies. A parliamentary inquiry into the Sydney fires has resulted in a greater focus on hazard reduction. As forests in NSW occur on a mixture of land tenures, legal, institutional and economic barriers limit the effectiveness of efforts to reduce wildfire risk. This paper introduces the concept of payments for ecosystem services (PES) and discusses successful schemes that have recently been implemented to reduce the risk of wildfires in catchments supplying water to the cities of Santa Fe, New Mexico and Denver, Colorado in the USA.

Key words payments for ecosystem services, PES; hazard reduction; water supply catchments; forest management

INTRODUCTION

One-third of the Australian population lives in the state of New South Wales (NSW) where forests cover 26.59 million ha or approximately 33% of the land area (ABARES, 2011). These forests occur on various land tenures including leasehold land (35%), private land (32%), National Parks and conservation reserves (17%), multiple-use State forests (9%) and Crown land (4%). In the most populated regions along the east coast and ranges, native *Eucalyptus* forests are largely relied upon to provide a continuous supply of high quality water for domestic, agricultural and industrial use (Webb, 2012a). This reliance on forests for water supplies in the Australian context is, however, potentially fraught as wildfires are a recurring feature of the landscape (Singh *et al.*, 1981). For example, the region surrounding Sydney, the largest city in NSW, has a long history of wildfires with significant recent events recorded in 1952, 1957, 1968, 1977, 1982, 1993/4 and 2001/2 (Dragovich & Morris, 2002a). North of Sydney, the fire season, when serious fires are likely to occur, runs from September to December. Around Sydney, and to the south, the fire season runs from October to January. However, occasional serious fires have been known to occur in February and March (Cheney, 1995). It is this part of NSW that experiences the most severe fire weather; high pressure systems in the Tasman Sea and low pressure systems in the Southern Ocean can create high pressure gradients that direct hot air from the arid interior of the continent to the southeastern part of Australia (Cheney, 1995). Essentially all of the vegetation, mostly dominated by *Eucalyptus* species, is susceptible to fire.

During December 1993 and January 1994, over 800 fires burnt >800 000 ha of forest in eastern NSW, destroying 287 premises and causing four deaths (Cheney, 1995). Similarly, in December 2001 and January 2002, the large "Black Christmas" wildfires burnt 733 342 ha of forest. These fires cost the NSW government A$217 million to suppress, cost a further A$80 million in insurance claims, destroyed 121 premises and caused injuries to 50 people. Despite the widespread nature of these severe fires and their proximity to high population urban areas, zero deaths were recorded (Coghlan, 2004). A salient point, however, is that the 2001/2 fires burnt 225 000 ha of forests within the source catchments supplying Sydney's water (Chafer *et al.*, 2004).

A wide range of soil erosion and water quality impacts due to wildfires in eastern NSW has been reported over recent decades. Blong *et al.* (1982), Atkinson (1984), Zierholtz *et al.* (1995)

and Dragovich & Morris (2002a,b) have all documented increases in hillslope soil erosion following bushfires in the greater Sydney region. However, as Prosser & Williams (1998) indicated, the risk of accelerated soil erosion and delivery to stream networks is highly dependent upon the timing and magnitude of rainfall events experienced in the post-fire period. On the south coast of NSW, Cornish & Binns (1987) and Mackay & Robinson (1987) observed changes in stream water quality following a wildfire that burnt part of a replicated paired catchment study. In the initial post-fire period, stream water cationic concentrations decreased relative to an unburnt control catchment and this impact was attributed to a relative increase in discharge in the burnt catchments. However, post-fire, cationic concentrations had increased relative to the pre-fire period after 3–4 years. Potassium concentrations increased in the year of the fire, as did Ca concentrations (Mackay & Robinson, 1987), yet turbidity levels remained unchanged. Due to heavy groundcover regeneration following the fire, turbidity levels in fact decreased to significantly below control and pre-fire levels five years after the catchments had been burnt (Cornish & Binns, 1987).

Following the 2001/2 Sydney fires, Wallbrink *et al.* (2004) reported that wildfires can potentially have a significant impact on downstream water quality within Lake Burragorang, the largest reservoir forming part of Sydney's water supply. The extensive wildfires in some areas were of extreme intensity, particularly on ridge-tops and flat–moderate (0–11°) northwesterly facing slopes, producing heat energy levels >70 000 kW m^{-1} (Chafer *et al.*, 2004). Varying effects on soil water repellency were observed ranging from no change to enhancement or destruction depending upon the soil temperatures attained (Shakesby *et al.*, 2003). In early 2002, a series of rainfall events post-fire resulted in accelerated soil erosion, redistribution of significant volumes of sediment on slopes and the storage and deposition of ash and sediment in rivers within the Nattai catchment (Blake *et al.*, 2009). High amplitude discharge peaks were observed, as were high turbidity, nitrogen and phosphorus concentrations (Wallbrink *et al.*, 2004; Blake *et al.*, 2009). Post-fire nitrogen, phosphorus and suspended sediment concentrations remained elevated for at least five years (Wilkinson *et al.*, 2006). However, post-fire bioturbation and litter dams on the foot slopes limited further downstream transport and propagation of sediment and nutrients (Shakesby *et al.*, 2007). Nonetheless, sediment deposition was evident in deltas where tributaries enter Lake Burragorang, but was lower in magnitude than the long-term pre-fire annual mean due to drought conditions and low annual water yields (Wilkinson *et al.*, 2006, 2007). It was concluded, however, that under worst-case scenario conditions, post-fire annual sediment yields to Lake Burragorang could be two to three orders of magnitude higher than the typical mean annual yield (Wilkinson *et al.*, 2007).

Despite some evidence that wildfires may not play a major geomorphic role in southeastern Australia (e.g. Tomkins *et al.*, 2007), Shakesby *et al.* (2007) stated that "*post-fire transfer of large proportions of the topsoil and its nutrients to watercourses has deleterious effects on downstream water quality*". In light of this and the destruction caused by the Black Christmas fires of 2001/2, a parliamentary inquiry has resulted in a greater focus on hazard reduction activities (NSW Parliament, 2002). This has been bolstered by more recent predictions of a 20–84% increase in potential large-fire ignition days under projected 2050 climate scenarios (Bradstock *et al.*, 2009). However, given that forests in NSW occur on a mixture of land tenures, legal, institutional and economic barriers limit the effectiveness of efforts to reduce wildfire risk with consequences for small and large water supplies.

Against the above context, this paper aims to outline current forest management within water supply catchments in NSW highlighting improvements required to reduce the impact of wildfires on river ecosystems, water supply and treatment. It further aims to introduce the concept of payments for ecosystem services (PES) by presenting two case studies from the USA where PES schemes are successfully being implemented to reduce the risk of wildfires in source water supply catchments. Feasible changes to existing management and institutional frameworks are evaluated for possible adoption in NSW.

MANAGEMENT OF FORESTS, FIRES AND WATER SUPPLY CATCHMENTS IN NSW

Water utilities

In NSW, there are 112 water utilities that supply water to cities and regional centres (Fig. 1). The bulk of these are local water utilities owned and operated by local councils delivering water to a combined regional population of 1.8 million (DPI, 2012). The two largest cities are served by the major state-owned water utilities, Sydney Water Corporation (Sydney) and Hunter Water Corporation (Newcastle), delivering water to populations of 4.4 million and 560 000, respectively. In addition to the state and local council operated water supplies, there are 19 independent water associations in NSW serving small regional communities (Webb, 2012a).

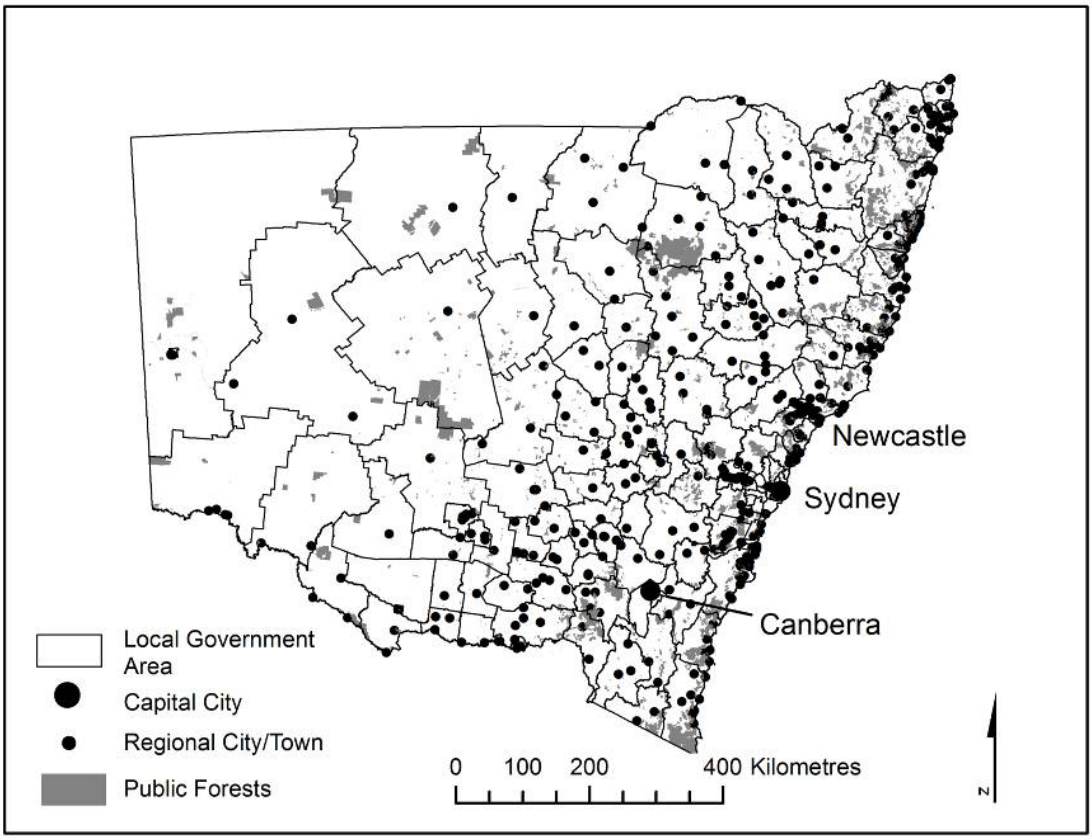

Fig. 1 The extent of publicly owned forests in relation to cities and local government areas in NSW. Note the extent of privately owned/leased forests is not shown.

Forest and catchment management

As mentioned in the Introduction, forests in NSW are located on a mixture of land tenures. In the majority of water supply catchments, the water utilities or catchment authorities rarely have control over the majority of the forests supplying water to streams and reservoirs (Webb, 2012a). This is even the case in the extensive 1.6 million ha catchments managed by the Sydney Catchment Authority (SCA), which delivers bulk raw water to the Sydney Water Corporation. The SCA has principal responsibility for managing the "special areas" closest to the reservoirs that mostly comprise native eucalypt forest. However, these areas comprise only 20% of the total catchments and the majority is held in conservation reserves managed subject to a memorandum of understanding between the SCA and the National Parks division of the NSW Office of Environment and Heritage (OEH) (SCA, 2007). The remainder of the catchments are a mixture of National Parks, State forests, Crown lands and private property over which the SCA has limited control. In the case of local council water utilities, the majority of their catchments comprise a mixture of private and state-owned lands over which they have minimal or zero jurisdiction.

The limited control of water utilities over forest and other land management within drinking water catchments poses problems for the effective management of water supplies in NSW. This is, arguably, exacerbated by the lack of an overall standard for the quality of water entering reservoirs and supply systems in Australia (McKay & Moeller, 2001). There is also limited scope for water authorities to promote or fund forest and other land management practices aimed at improving inflow water quality.

Fire management

To complicate matters further, fires are managed by four separate state government agencies. Fires on National Parks fall within the jurisdiction of the National Parks and Wildlife Division of OEH; Forests NSW has jurisdiction over fires on State forests and Crown timber-lands; the NSW Fire Brigade has control over metropolitan fires, while the NSW Rural Fire Service is tasked with providing services for the prevention, mitigation and suppression of fires in rural fire districts (Gillen, 2005).

The SCA has developed joint fire management plans for the special areas within the Sydney catchments with OEH (SCA, 2007). These plans cover activities such as fire trail maintenance, hazard reduction burning and rapid response strategies in the event of wildfires. However, as mentioned, SCA does not have control over the remaining 80% of the catchments and is reliant upon other landowners to manage fires. Hunter Water Corporation also acknowledges the risk that wildfires potentially pose for water quality and is in the process of developing a bushfire management plan in consultation with other stakeholders (Hunter Water, 2011). In the case of local water utilities, they do not have any jurisdiction over fire management and so potential effects on water quality are at the whim of hazard reduction and suppression activities undertaken by State government agencies. Furthermore, the majority of water utilities are small and lack the funds and resources (Woodbury & Dollery, 2004) to contribute to reducing the risk of wildfires.

PAYMENTS FOR ECOSYSTEM SERVICES: AN ALTERNATIVE APPROACH

"Ecosystem services" are goods and services provided by ecosystems for the benefit of humans (Daily, 1997; MEA, 2005). A specific category of ecosystem services that relates purely to catchments or watersheds has been termed "hydrologic services" (Brauman *et al.*, 2007) or "watershed services" (Stanton *et al.*, 2010). Examples include the provision of water for domestic, agricultural, commercial, industrial and hydro-electric power generation purposes; the supply of fish and other freshwater products; reduction of flood damage; prevention of soil erosion and sedimentation of waterways and reservoirs; and recreation and aesthetic values (Brauman *et al.*, 2007).

Broadly defined, payments for ecosystem services (PES) are a payment or exchange of credits between a buyer and a seller to effect some improvement of an ecosystem service (Stanton *et al.*, 2010). A subset of PES schemes dealing with watershed services is called payments for watershed services (PWS) schemes and these can be grouped into Government PWS, Private PWS and Water Quality Trading (WQT) schemes (Webb, 2012b). Government PWS schemes involve a government agency as the buyer of watershed services, sometimes on behalf of others, from upstream land owners. Payments take many forms including economic incentives to change land use practices, subsidies, cost-sharing arrangements, tax relief, land purchase deals and the purchase of conservation easements (Webb, 2012b). Private PWS schemes are rare and involve payments wholly by a private entity to upstream land owners to protect a watershed service for either business reasons or philanthropic interests. Water quality trading schemes involve a framework whereby a cap on pollution loads is set by regulation and the regulated entities purchase and trade in offset credits to meet their obligations (Shortle & Horan, 2001).

The number of PWS schemes, and the area of land protected, is expanding worldwide. In the USA alone in 2008, PWS transactions exceeded US$1.3 billion and operated across 16.4 million ha (Stanton *et al.*, 2010). While these schemes operate by exchanging payments or credits for watershed services in one way or another, there is often a driver leading to their existence and ultimate success or failure. Typically the drivers are regulatory and/or economic (Webb, 2012b). In the USA, an interesting development has been the introduction of PES/PWS schemes to reduce the risk of wildfires in water supply catchments. Two such case studies are presented below.

Santa Fe, New Mexico

The city of Sante Fe, New Mexico, has adopted an innovative scheme to reduce the risk of wildfires within its water supply catchment. The author visited the city and water supply catchment in April 2011 and conducted interviews with personnel from the US Forest Service (USFS) and Santa Fe Watershed Association.

The Santa Fe region experiences a cool semi-arid climate where wildfires are not uncommon (Steelman & Kunkel, 2004; Gutzler & Van Alst, 2010). The city lies at an elevation of 2130 m at the foot of the Sangre de Cristo Mountains and today has a population of ~75 000. The Santa Fe Municipal watershed supplies up to 50% of the water used, the remainder coming from groundwater wells. The watershed is ~6954 ha in area, of which the City owns and manages around 400 ha near the dams and riparian zones. The rest of the watershed comprises the Santa Fe National Forest in the lower watershed and the Pecos Wilderness Area (~4000 ha) in higher parts. These forested areas are managed by the USFS and not the City.

For more than 100 years, the Santa Fe watershed forests have been managed with a philosophy of complete fire suppression and this has led to the stands becoming overstocked, vulnerable to pest or insect attack, and highly prone to intense stand-replacement fires with drastic consequences for soil erosion and contamination of the local water supply (Santa Fe, 2009). Having witnessed the effects of the Hayman and Buffalo Creek fires on water supplies in Denver, Colorado (e.g. Moody & Martin, 2001; Robichaud *et al.*, 2008), as well as the 2000 Cerro Grande fire that resulted in a 140-fold increase in sedimentation of the Los Alamos reservoir (Reneau *et al.*, 2007), a consensus decision was made that Santa Fe needed to act. Discussions began in 2007 and culminated in the Santa Fe Municipal Watershed 20-Year Protection Plan which is unique in that it "*seeks to fund forest restoration activities using the payments for ecosystem services model as an insurance policy against future threats, particularly of catastrophic fire, to the municipal water supply*" (Santa Fe, 2009). The major signatories are the USFS, Santa Fe Watershed Association, the Nature Conservancy, City of Santa Fe Water Division and the City of Santa Fe Fire Department. The cost of the Plan is estimated to be US$4.3 million over 20 years. By comparison, investing in the catchment would avoid an estimated repair bill of US$22 million if 2800 ha of the watershed were to burn. Without hazard reduction, the likelihood of such a fire was estimated to be one in five in any given year (Santa Fe, 2009).

The four critical components of the Plan are vegetation management and fire use; water management; public awareness and outreach; and financial management based on PES. Between 2003 and 2006, mechanical treatments were carried out across 2114 ha of forests in the areas dominated by Ponderosa pines (<3050 m). The pines were thinned using a "mastication" method that reduces trees to large strips or chunks of wood that can more easily be burnt as part of hazard reduction. The aim of the thinning and mechanical treatments is to separate the crowns to reduce the risk of crown fires (Fig. 2). Under the Plan, some additional mechanical works have been outlined which include the targeted reduction of undergrowth to reduce the density of piñon-juniper woodland.

In the Santa Fe National Forest, there is a plan to undertake regular hazard reduction burning across the already treated areas. The aim is to burn approximately 400 ha per year with the entire area of the lower watershed being burned once every seven years. In the Pecos Wilderness Area, which covers predominantly the highest elevation areas in the watershed, Federal regulations preclude any mechanical thinning or similar interventions. However, prescribed burning can be undertaken. The wilderness area at lower elevations comprises mixed conifer forests, including Ponderosa pines, Piñon pines and Gambel oak. At these elevations, there are plans to undertake prescribed burns to reduce fuel loads. Under the regulations it is also possible to undertake strategic hand thinning to break up fuels and this will be considered. To somewhat protect the wilderness area, mechanical thinning will be undertaken on ridges adjacent to its borders. At higher elevations (>3050 m) in the wilderness area, the predominant forests are spruce and fir stands within which active management activities are not planned (Santa Fe, 2009).

The Plan is at first being funded by federal funds obtained from Congress allocations. However, from 2014 the USFS's work in the watershed will need to be funded by cost-sharing arrangements. To that end, the plan is to establish a PES scheme that leverages US$0.65 per month from water users in the City as part of their service rate charges. Underpinning much of the selling of the scheme is the public education and outreach programme. This is being handled by the Santa Fe Watershed Association and includes a number of initiatives including taking the general public on supervised educational hikes through the watershed, conducting field days with school groups, presentations to primary school classes, involving high school students in water monitoring activities, staffing educational tables in the city, distribution of newsletters, placing an information page in the telephone book and developing 30-second television advertisements (Santa Fe, 2009).

According to surveys conducted on behalf of the Nature Conservancy, the PES scheme is supported by 76% of Santa Fe residents (Felicity Broennan, written communication, 14 July 2011). Based on this level of support, the PES scheme is likely to be a success. However, despite the investment and work undertaken, there can be no guarantee that a wildfire will not occur. If it does, the "insurance" work is designed to mitigate its impact upon the water supply.

Fig. 2 Stands of Ponderosa Pine recently thinned to separate the crowns and reduce wildfire risk in the Santa Fe watershed.

Denver, Colorado

A brief summary of the PES scheme operating in Denver's water supply catchments is provided here as it has been described in greater detail by Webb (2012b). Denver Water is a non-profit public utility that supplies drinking water to around 1.3 million people. Its watersheds total one million ha across four river basins delivering water to 15 major reservoirs. Much of the land in the watersheds is forested public land managed by the USFS and not Denver Water.

The PES scheme has originated in response to a number of large wildfires experienced in the watersheds in recent decades (Moody & Martin, 2001; Robichaud *et al.*, 2008). The Hayman fire alone caused US$38 million in property damage, cost US$42 million to suppress, and between Denver Water and the USFS cost US$48 million to remediate. There was an acknowledgement from both agencies that management of National forest land was impacting in an adverse way on Denver Water's business. Denver Water had no jurisdiction over such land and could not ensure the USFS would undertake appropriate management. The USFS was aware of Denver Water's requirements, but could not undertake the required management due to limited appropriated funds.

Following much negotiation, on 29 July 2010 Denver Water and the USFS signed a five-year Memorandum of Understanding titled "Restoring forest and watershed health to protect the City and County of Denver's municipal water supplies and infrastructure". The deal will see Denver Water and the USFS each contribute US$16.5 million towards restoring various watersheds. Hazard reduction activities such as forest thinning and rehabilitation of previously burnt areas will occur. The PES scheme will be funded in part by payments of US$27 per household in total over five years by Denver Water's customers. Denver Water has been running a comprehensive education campaign and the USFS is committed to engaging communities in forest and conservation management projects. The combined effort of these agencies has contributed to substantial local support for the PES scheme (Webb, 2012b).

CONCLUSIONS

Recent history and scientific investigations indicate that extreme wildfires can and do occur in the forests of NSW, with potentially disastrous consequences for water supplies essential for a range of stakeholders. The existing management of forests, water supplies and fires within NSW is complex and there exist institutional, economic and legal barriers to the effective reduction of wildfire risk within source water supply catchments. Principal among these is the inherent lack of jurisdiction of water utilities over forest and fire management.

Payments for ecosystem services schemes offer an alternative approach, whereby downstream users of the water resource pay additional water rates that are used to fund appropriate hazard reduction activities to reduce the risk and severity of wildfires. Initiation of such schemes by water utilities in Santa Fe and Denver demonstrates that market instruments can be utilised to overcome the identified institutional, economic and legal barriers. Similar schemes have been successfully implemented around the world to reduce the impacts of land use (e.g. O'Grady, 2011) and wastewater treatment (e.g. Cochran & Logue, 2011), with water quality improvements often negating the need for expensive treatment plants (e.g. Salzman, 2011). Payments for ecosystem services scheme funds and appropriate memoranda of understanding could successfully be used by NSW water utilities, large and small, to pay forest and fire management agencies for hazard reduction activities to improve water quality.

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