Australian Marketing Perspective Coal Ash for Agriculture

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ABSTRACT
Opportunities exist to market the Australian CCP as a beneficially equitable product. In Australia we currently operate with a 7 million tonne annual surplus to existing market demand. Weaknesses in the current marketing mix for agricultural opportunities are the lack of strong economic drivers, and a lack of value as driven through existing product competition. This lack of value, in part, is due to coal ash being labeled as 'wastes, which sustains the perception of environmental risks associated with CCPs.

Marketing and promotion efforts of CCPs should incorporate better understanding of legislative frameworks which facilitate to beneficial reuse of CCPs and acknowledge the environmental risk which can be managed as an ongoing factor. There is also a lack of communication between the potential market and supply organizations, which represents a current lack of promotional push. We consider that the market for Australian CCPs is a sustainable *choice* for the agricultural landholder, rather than as a substitute to existing production methods with gypsum, lime fertilizers and or composted organic material. Coupled with the use of existing products multiple benefits will be realized through a general purpose soil amendment. This paper discusses the need to develop a new national supply model for the Australian coal ash industry to support a range of agricultural enterprises at local, national or global scales, within a long term commitment to agricultural production, national food security and sustainable coal fired operations.

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INTRODUCTION

One premise for an agriculture based coal ash market is that obligations for national food security and natural resource management can be met within commercial realization. Such a marketing perspective will enable a significant transformation in the rate of coal ash to sustain new market sectors. For opportunities in agricultural markets to be realized a new national supply model for the Australian CCP industry is well overdue. In current context the market has few if any examples of practical applications for CCP use on farm, with reported in 2012 in the Ash Development Association of Australia membership survey noting only 600 t or 20 truck-loads of fly ash were apportioned to an agricultural use [1].

Australian coal resources are located in six major coal basins across Queensland, Victoria, South Australia, Western Australia and New South Wales (Figure 1) with supply to 31 power stations and all well represented by Australian publications relevant to the use of coal fly ashes for agronomic purposes [2]. This is an industry currently operating with significant supply opportunities to the agricultural sector. Production coal ash is 12-14 Mt - with about 25 % directly sold at source for cement [1], leaving at least 8.7 Mt of fly ash and 1.0 Mt furnace bottom ash potentially for agriculture or other commercial markets as surplus, in excess of existing market demand with the locations of these resources intermittently dispersed.

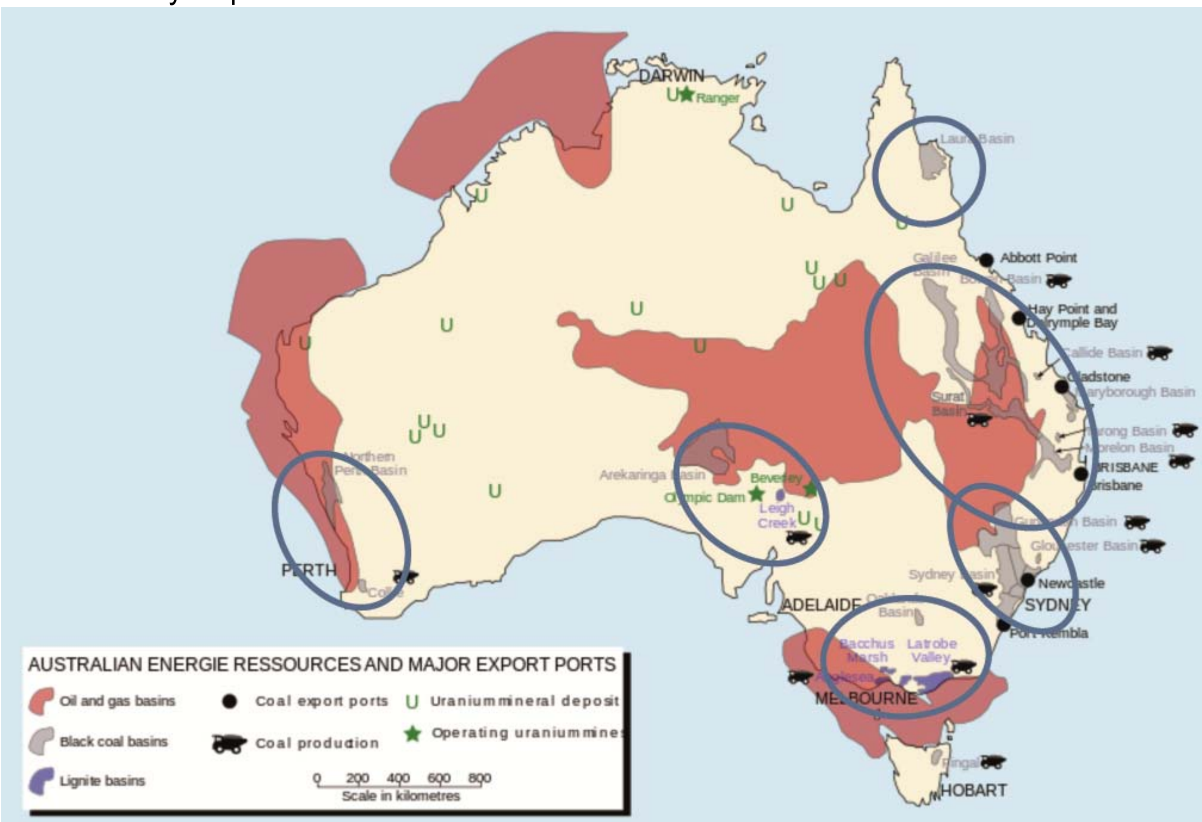

Figure 1, Identification of Australian coal basin locations as Australian agricultural regions. http://en.wikipedia.org/wiki/Coal_mining_in_Australia, Accessed: 12/7/13

Achieving alternatives for CCP use in other than for cement industry has required a change in context from 'waste' within the premise of changed perceptions in value for a tradable commodity. One real driver for change in Australia is sustained through a resource recovery policy [3] promoting CCPs to civil or engineering and soil based industries such as agriculture [4-6], building on the advocacy for a framework of legal certainty, which has been a priority of the World Wide Coal Combustion Products Network [7].

Soil opportunities technically are well defined within the current framework for use, initiated at the production source through a regulatory framework within resource recovery policy. To complement this approach research interpretations indicate that fly ashes for soil amendment can complement existing production methods through applications in alternate years to provide multiple benefits [4, 8]. Similarly, Australian researchers have continued to demonstrate the capacity for and response to coal ash incorporations with soil [8-10], including characterization of limitations to plant growth or toxicity to plants [11-12], boron uptake and solubility [13,] improvement in nutrient (N and P) retention in a sand soil [14, 15] as well as studies for release of trace elements [16], increased water holding capacity [17] and earthworm survival [18].

Despite a strong research representation for CCPs to agricultural soils and the current advocacy strategies of associations like the Ash Development Association of Australia (ADAA), the use in soil applications for agricultural areas remain an unrealized market. With neither mode of action nor soil response a limiting issue for market uptake, then market limitations are in the supply chain to the consumer. This paper discusses market opportunity presenting a position strategy toward market harmonization.

THE LONG ROAD TO LEGAL CERTAINTY

Australia now has a well-defined selection process to identify appropriate materials for soils applications including agriculture, through resource recovery regulations in place for Queensland and New South Wales. In New South Wales the Environment Protection Authority (EPA) assessment and approval mechanism is within the scope of Protection of the Environment Operations (Waste) Regulation currently 2014 [3]. Using defined thresholds for maximum chemical concentration and regular testing intervals to ensure environment protection is maintained then combined with conditions for application, an approval for resource recovery outlines responsibilities for the supplier, processor or consumer [5-6]. This similar process is also available in Queensland though their state government environment protection legislation [19].

The NSW EPA coal ash exemption (CAE) has been through several iterations since first being gazetted in 2005 under Part 6, Clause 51 and 51A to the Protection of the Environment Operations (Waste) Regulations 2005. Through the Ash Development Association of Australia, on behalf of members, coal ash general exemption documents have under gone continuous refinement and improvements for coal ash use in soils and civil engineering purposes. Previously gazetted exemptions include;

- The fly ash and bottom ash from burning NSW or Queensland coal exemption 2006, commencing 1st December 2006 for the purposes of growing vegetation, revoked 24th November 2014.
- The coal ash exemption 2010, commencing 5th June 2010 for the purposes of engineering, revoked on 14th June 2011.
- The coal ash exemption 2011, commencing 14th June 2011 for the purposes of engineering, revoked 22nd April 2013.

The coal ash exemption 2013 for the purposes of engineering, commencing 22nd April 2013, revoked on 24th November 2014.

What has changed? In November 2014 the Association negotiated order and exemption were re-published under Part 9 Clause 93, in line with the recently gazetted Protection of the Environment Operations (Waste) Regulation 2014 [3].The regulation now defines Resource Recovery into two parts, a Resource Recovery Order and Resource Recovery Exemption.

‘The coal ash exemption 2014’ [6], commencing 24th November 2014 applies to persons who *apply or intend to apply,* coal ash or blended coal ash to land as an engineering material and for the purpose of growing vegetation.

‘The Coal ash order 2014’ [20] is in relation to the *supply* of coal ash and blended coal ash for application to land for land based application (soils and engineering) in line with the uses described in ‘The coal ash exemption 2014’ [6]

In separating responsibility into an Order and Exemption the threshold limits, the suite of chemical or other test attributes, and the methodologies of sampling and testing programs has remained unchanged. All sampling frequencies prior to November 2014 are replicated into the new Order and Exemption with compliance to Australian Standards except a specifically defined sampling frequency is provided as a reduced sampling frequency if the coal ash generated for land application as a soil amendment. To obtain the Coal ash Order 2014 (CAO) and the Coal ash Exemption 2014 (CAE), download from http://www.epa.nsw.gov.au/wasteregulation/orders-exemptions.htm

With new markets available to coal ash reuse through Ash Development Association of Australia (ADAA) negotiated resource recovery exemptions the scope to agriculture, in civil construction including pavement materials, backfill and embankments, and cementitious and concrete manufacture is initiated. In real terms the concept for resource recovery exemption is a preface to commercial opportunity, facilitating the formation of markets within a context of fit-for-purpose materials such as matching for soils applications. A resource recovery opportunity through CAO or CAE such as those of the NSW Environment Protection Authority is now the framework of legal certainty, for all state corporate, commercial decision-making processes, including the premise of supply into the agricultural sector.

THE PRODUCT

Brown and black coals are used in Australia, with black coal being the predominant fuel for production coal fly ash and furnace bottom ash. Brown coal fly ash has higher salinity, associated with chloride and sulfate. Australian black coal furnace bottom ash and fly ash are generally low salinity, total elemental boron < 10 mg/kg, low soluble boron, with sulfate and chloride the primary variables between source ashes. The fly ashes are diverse and yet consistent in their chemical and physical properties. Their pH ranges from highly acidic to a highly alkaline with salinities non-saline, saline or sodic [4, 8]. Chemically composition is classified as Class F with < 10 % compositions of CaO. The Australian black coal fly ashes at < 3 % calcium, a magnesium range of < 1-11 %, negligible nitrogen, phosphorus and potassium occurs across a pH range of 4 – 12. These ashes are not replacement materials for fertilizer, gypsum, or lime, and at best the brown coal may substitute a poor quality dolomite. They are generally low in heavy metals and sulfur [4, 8]. The chemical composition for example of an acidic fly ash from the Sydney Basin western coal field is predominately 65-68 % silicon dioxide, 23-25 % aluminium oxide, 1-2 % iron oxide, and the remaining 3 % comprising all other elements, including calcium and magnesium. These are characteristics unlike a European or American coal ash.

In this context, given the unique chemical characteristics of Australian coal ash, two applied research approaches have been instigated through ADAA investment [2, 8, 21].

Considerations as to how these Australian fly ashes from coal combustion could be employed have formed the basis of the work published by [8] who identified significant properties of the Class F ashes that will contribute to the practical applications for specified use of these materials to soils. Here the main aspects of those findings are summarized (Table 1).

Table 1, Properties of Australian class f fly ashes for agriculture [8]

1. Australian Class F fly ashes could raise the pH of amended acidic soils over an extended period as a result of gradual dissolution of the amorphous silicates and slow release of cations embedded in the silica structure.
2. Positive responses in plant growth to fly ash addition often tend to be associated with a combination of factors, such as liming effects, nutrient supply and improvement in soil physical conditions.
3. The potential for phytoxicity from most Australian ashes is relatively low, because these ashes, unlike many from overseas, are relatively low in trace element concentrations.
4. The risk of Al dissolution due to low pH is non-existent with acidic FA additions. The mechanism proposed is based on long term aluminosilicate dissolution and Ca release that raises the pH toward neutral.
5. The risk of phytoxicity can be further minimised by using ashes at agronomically sustainable rates, similar to those used for other agricultural soil amendments such as gypsum and lime.
6. Most of the benefits from the use of fly ash can be obtained at application rates not exceeding 10 t/ha, and for most purposes not more than 5 t/ha.
7. With the exception of fly ashes derived from brown coal, all the other ashes used in these studies easily met the regulatory standards set in New South Wales and Queensland.
8. On the basis of research recommendations the primary qualifier for fly ash use in Australian agriculture is a material with threshold metal element concentrations below 100 mg/kg lead, 10 mg/kg cadmium and 5 mg/kg mercury [8]. In these respects, Australian brown and black coals are similar.

SITUATIONAL SUMMARY

The agricultural market supply chain, being independent of current industry stakeholders has 7-9 Mt fly production ashes to draw off as source materials from tonnages stored [1]. This is a market across environmental management, sustainability and resource management. It can, within an appropriate application of technology draw from over 400 million tonne of stored materials located nationally [4, 22]. Starting with a framework to verify material suitability to the land based applications, such as agriculture, the CCP is low risk in phytoxicity with benefits to soil management choices. In Australia there are predictions for sustainable soil responses and an established baseline agronomic rate with potential to address constraints to plant production. However, with focus still all about resource recovery, establishing a derived product value has broad implications.

Technically, customers do not buy products they by product benefits [23]. A review of our marketing strengths indicates the Australian CCP material will not compete as a substitute product such as gypsum, but are a choice for the agricultural landholder rather than as a cheaper replacement to existing products [24]. Additions of fly ash will either prolong the traditional amendment benefits or work as an independent product, to improve plant yield and soil structural properties over time.

Coupled with the use of existing products and existing production methods with gypsum, lime fertilizers and or composted organic material, benefits of the Australian low sulfur CCP are multiple-benefits, realized through a general purpose soil amendment. Benefits to soils are micronutrients, secondary season retention, and in combination the fly ash is a lower cost product choice and an alternative soil ameliorant in variable years. Thus, over time plant yield response will decline with conventional soil amendment (Figure 2), which is the premise with which to establish and assess field trial success.

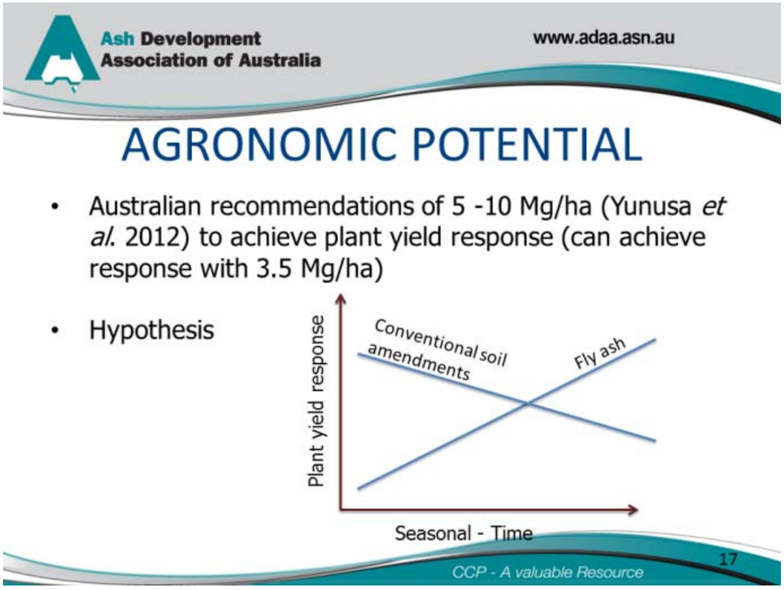

Figure 2, General hypothesis for soil benefit and agronomic potential with Australian fly ash CCPs.

GAP ANALYSIS

Supply capabilities for Australia are a national opportunity for industry to target and build on the utilization of 25 % of 12-14 Mt production developed by the cement industry [1]. The question is; what likelihood or feasibility is there in using the remaining 75 % production to agriculture?

At present our industry lacks strong economic drivers although we continue advocating the idea of selling or using ash. We are viewed as a resource recovery industry, applying wastes for land applications through the policy of resource recovery, and as will continually need to prove benefit. Currently the commercial price has no other value that its comparison to conventional soil amendment products, the cost of freight [8], or the cost of storage [24], and neither will achieve the desired outcome for realistic commercial exchange. In real terms the rate of farmer acceptance is the market, based on favourable outcomes from field trials as plant yields are matched to cost effectiveness, however to date, we have no field trials in place, and establishment will take several seasons or years. So until commercial benefits can be fulfilled on-farm an appropriate value cannot be defined. What should be done to action this?

MARKET OPPORTUNITY

Currently, the market opportunities in the agriculture sector are those that solve nationally represented soil problems limiting productive capacities. The Ash Development Association of Australia (ADAA), through funding development projects [8, 21] identifies that potential for agricultural use with fly ash cover-off four major soil problems for agricultural producers and their profits. Soil acidity, soil sodicity, nutrient supply and minimization of nutrient losses and amelioration of soil structural and hydrological properties represent the major constraints to plant growth and crop yield, at a cost to the industry profit of almost $3 billion annually [8]. Soils-based applications linked to enhancement, capture and protection of atmospheric carbon in soil due to fly ash addition as a new area, also offers substantial potential in the abatement of carbon emissions in agriculture [8], with opportunities to improve food security and sequester carbon [25, 29]. Market opportunities for Australian coal ashes are in these five aspects of soil management [24].

Two market opportunities for coal ash and agricultural soils are the acidified and sodic soils. If for example, the objective is to ameliorate low soil pH with coal ash then this could be a national priority. Acidification influencing Australian agriculture [25-27] is a well-documented zone across Western Australia, the coastal and tablelands areas of the eastern seaboard from Adelaide in South Australia and through to the mid-Queensland coast (Figure 1). The potential market, based on soil pH conditions is an estimated 50 million hectares of highly < pH 4.8 and moderately acidic pH (4.8-5.5) soils found mostly along coastal agricultural regions that receive good rainfall [28]. To service market potential, we have Australian alkaline coal ash resources intermittently dispersed within regional coal basins (Figure 1). However, for application to soils at a rate of 1.0 t/ha fly ash, the CCP production rate will not cater for potential demand in terms of soil acidity remediation. Neither will accesses into these sites on farms be achieved because product network distribution has no commercial supply chain.

Similarly, there is the market potential across a significant land area for fly ashes with chemical properties to improve sodic soils [4, 8]. Again, in Australia whilst we do have fly ashes with low SAR values that can replace or supplement gypsum [8], ash production is not adjacent to these agricultural areas, and consequently examples that demonstrate remediation of soil sodicity are also still lacking and examples to demonstrate supply have not been reported.

With significant logistical implications for a market to service the agricultural sector that include the broad nature of the distribution within a wide range of stakeholders, commercial interests, marketing competition and potential limits to supply volumes; particularly within the intermittently located sources of alkaline ashes across the nation and widely distributed acidic soils - undeniably Australian perspectives of the coal ash industry need to change.

Within review of marketing strengths [24] the option of CCP supply is general purpose soil amendment commonly purchased through existing agricultural supply companies. This approach addresses a market transformation, from low-value - high-volume localized output into a high-value, high-volume nationally distributed fly ash CCP. Consequently a unified and national approach to distributing product will be critical for achieving solutions to soil acidity and soil sodicity, both for maintenance in supply and equity in specification. In this context the logistics in transport and monitoring and evaluation of material and the end use, will remain important components to establishing the CCP supply chain to service the potential of a market into the Australian agricultural sector.

CONCLUSION

Overall, the market status for coal ash for agriculture in Australia is highly regulated, with high commercial risk to supplier, processor or consumer, a lot of unknown commercial factors and a lot of unknown and unproven opportunities. Australia’s current development of the market supply chain is relying on advocacy through the Ash Development Association of Australia, or customer demand. A stage-one supply chain analysis indicates the current model of advocacy has opportunity but no commercial ash sales and gaps in supply start at the production source. With opportunity as a soil amendment well defined for the Australian fly ashes, with eight main aspects of product characterization and mode in soil response identified a commercial and sustainable market and its supply can be engaged through a unified and national approach.

REFERENCES

[1] HBM Group. Ash Development Association of Australia, Annual Membership Survey Results January – December 2012. ADAA National Office, Wollongong, Australia. http://www.adaa.asn.au/documents/ADAA_Mship_Report_2012.pdf: Accessed 7th December 2013; 2012.

[2] Aiken JT, Heidrich C. Market opportunities for coal ash within Australian agriculture. In: Proceedings of the Soil Science Australia National Soil Science Conference: Securing Australia's soils - for profitable industries and healthy landscapes. Melbourne. (Eds A Patti, C Tang and V Wong). (Australian Society of Soil Science Inc.) ISBN: 978-0-09586-595-2-9; 2014.

[3] New South Wales Government. Protection of the Environment Operations (Waste) Regulation 2014. www.epa.nsw.gov.au/wasteregulation/poeo-reg-2014.htm: 2014.

[4] Yunusa IAM, Eamus D, DeSilva DL, Murray BR, Burchett MD, Skilbeck GC, Heidrich C. Fly ash: An exploitable resource for management of Australian agricultural soils. Fuel 2006: 85, 2337-2344.

[5] Environment Protection Authority NSW. Protection of the Environment Operations (Waste) Regulation 2005 – General Exemption Under Part 6: The fly ash and bottom ash from burning NSW or Queensland coal exemption 2006. Office of Environment and Heritage: http://www.environment.nsw.gov.au/waste/generalRRE.htm: 2006.

[6] NSW EPA, New South Wales Environment Protection Authority. Resource Recovery Order under Part 9, Clause 93 of the Protection of the Environment Operations (Waste)

Regulation 2014, The coal ash exemption 2014.
www.epa.nsw.gov.au/resources/waste/rre14-coal-ash.pdf*:* 2014.

[7] Heidrich C, Feuerborn HJ, Weir A. Coal Combustion Products: A Global Perspective. World of Coal Ash 2013. Lexington, Kentucky USA, CEAR & ACAA. Vol 1: pgs 17. http://www.flyash.info/; 2013.

[8] Yunusa I, Manoharan V, Burchett, M, Eamus D, Skilbeck G. Utilisation of Coal Combustion Products in Agriculture. In 'Coal combustion products handbook'. (Eds L Gurba, C Heidrich, C Ward) pp 373- 414. (Cooperative Research Centre for Coal in Sustainable Development. Australian Black Coal Utilisation Research Limited: Australia); 2007.

[9] Yunusa IAM , Loganathan P, Nissanka SP, Manoharan V, Burchett MD, Skilbeck, CG, Eamus D. Application of Coal Fly Ash in Agriculture: A Strategic Perspective. Critical Reviews in Environmental Science and Technology 2012: 42, 559–600.

[10] Pathan SM, Alymore LAG, Colmer TD. Properties of several fly ash materials in relation to use as soil amendments. Journal of Environmental Quality 2003: 32, 687-693.

[11] Aitken RL, Campbell DJ, Bell LC. Properties of Australian Fly Ashes Relevant to their Agronomic Utilization. Australian Journal Soil Research 1984: 22, 443-53.

[12] Spark KM, Swift RS. Use of alkaline flyash-based products to amend acid soils: Extractibility of selected elements and their uptakes by plants. Australian Journal Soil Research 2008: 46, 585-599.

[13] Manoharan V, Yunusa IAM, Loganathan P, Lawrie R, Murray BR, Skilbeck CG, Eamus D. Boron contents and solubility in Australian fly ashes and its uptake by canola (*Brassica napus L.*) from the ash amended soils. Australian Journal of Soil Research 2010: 48, 480-487.

[14] Campbell DJ, Fox WE, Aitken RL, Bell CL. Physical Characteristics of Sands Amended with Fly Ash. Australian Journal Soil Research 1983: 21,147-154.

[15] Pathan SM, Almore LAG, Colmer TD. Reduced leaching of nitrate, ammonium and phosphorus in a sandy soil by fly ash amendment. Australian Journal of Soil Research 2002: 40(7), 1201-1211.

[16] Seshadri B, Bolan NS, Naidu R, Brodie K. The role of coal combustion products in managing the bioavailability of nutrients and heavy metals in soils. Journal of Soil Science and Plant Nutrition 2010: 10, 378-398.

[17] Pathan SM, Aylmore LAG, Colmer TD. Fly ash amendment of sandy soils to improve water and nutrient use efficiency in turf culture. International Turfgrass Society Research Journal 2001: 9, 33-39.

[18] Muir MA, Yunusa IAM, Burchett MD, Lawrie R, Chan KY, Manoharan V. Short-term responses of two contrasting species of earthworms in an agricultural soil amended with coal fly ash. Soil Biology and Biochemistry 2007: 39, 987-992.

[19] Department of Environment and Heritage Protection. General Approval of a resource for beneficial use—Coal Combustion Products (CCPs) used in bound final products, Permit number: ENBU01043609. Queensland Government. https://www.ehp.qld.gov.au/waste/pdf/coal-combustion.pdf: 2010.

[20] NSW EPA, New South Wales Environment Protection Authority. Resource Recovery Order under Part 9, Clause 93 of the Protection of the Environment Operations (Waste) Regulation 2014, The coal ash order 2014. www.epa.nsw.gov.au/resources/waste/rro14-coal-ash.pdf: 2014.

[21] Pathan SM. Fly Ash Amendment of Sandy Soils To Improve Water and Nutrient Use in Turf Thesis. Agriculture and Plant Sciences, University of Western Australia: 2003.

[22] Heidrich C. Ash Utilisation – an Australian perspective. International Ash Use Symposium, Centre for Applied Energy Research, University of Kentucky, 2003. http://www.flyash.info/: 2003.

[23] Christopher M. 'Logistics and Supply Chain Management – Creating Value Adding Networks'. Prentice Hall: 2005.

[24] Aiken JT. Marketing Plan for Coal Ash within Australian Agriculture. Jane T. Aiken Consultancy, A formal submission to the Ash Development Association of Australia. Environmental Studies Consulting (Soil Health Ecology) Coal Ash Innovations, Lithgow NSW: 2014.

[25] Ukwattage NL, Ranjith PG, Bouzza M. The use of coal combustion fly ash as a soil amendment in agricultural lands (with comments on its potential to improve food security and sequester carbon). Fuel 2013:109, 400-408.

[26] Barson M, Mewett J, Paplinska J. Land management practice trends in Australia's broadacre cropping industries. Caring for our Country Sustainable Practices fact sheet 3. Department of Agriculture, Fisheries and Forestry, Canberra: 2012.

[27] Yunusa I, Manoharan V. Mitigating soil acidity and minimizing recharge of groundwater through coal-ash treatment. Final report for Project ENV13/04. Murray irrigation Limited, Deniliquin NSW: 2005.

[28] Dolling PJ, Moody P, Noble A, Helyar K, Hughes B, Reuter D, Sparrow L. Soil acidity and acidification, Final report to National Land and Water Resources Audit for Project 54C, available as zip file through Australian Natural Resources Atlas, <http://auditeagovau/anra/land/docs/soil_acid/soil_acidity_final_reportzip>: 2001.

[29] Palumbo AV, McCarthy JF, Amonette JE, Fisher LS, Wullschleger SD, Lee Daniels W. Prospects for enhancing carbon sequestration and reclamation of degraded lands with fossil-fuel combustion by-products. Advances in Environmental Research 2004: 8, 425-438.