Market Opportunities for Coal Ash within Australian Agriculture

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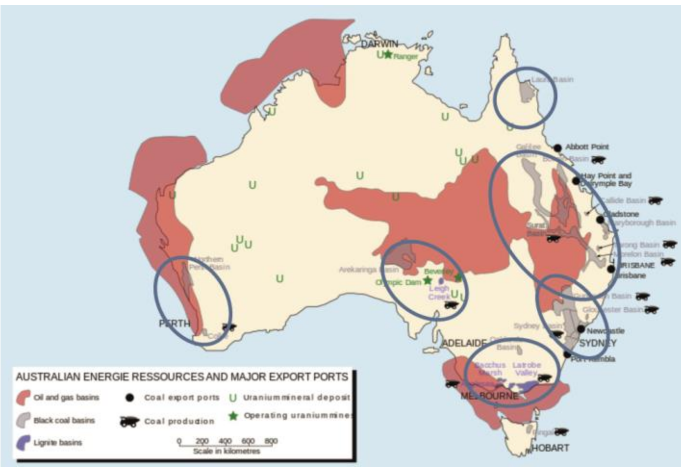
Extended Abstract

Introduction

One avenue available to the coal ash industry is the development of markets that use coal combustion products or coal ash in agricultural production. Market development has been supported by the Ash Development Association of Australia (ADAA) through its advocacy and educational programs. Similarly Australian researchers support coal ash use and advocate ash suitability to improve agricultural productive capacities. There are however, few practical examples of ash resources being used within the Australian agricultural sector. This paper presents a brief discussion on current market opportunities for coal ash within the Australian agricultural sector. These are opportunities supported by the recent advances in soils knowledge that also offer solutions to soil constraints that limit agricultural profits. Material processing is an option identified for further development.

Australian coal ash producers, processors and marketers are represented through the ADAA which was formed in 1990. The national membership provides coverage of all states and major coal basins of Queensland, Victoria, South Australia, Western Australia and New South Wales (Fig. 1). These locations are well represented by Australian publications relevant to the use of coal fly ashes for agronomic purposes by Australian researchers who continue to demonstrate the capacity for and response to coal ash incorporations with soil (Yunusa *et al.* 2012; Manoharan *et al.* 2010; Seshadri *et al.* 2010; Spark and Swift 2008; Muir *et al.* 2007; Pathan *et al.* 2003; Pathan *et al.* 2002, Pathan *et al.* 2001; Summers *et al.* 1998; Aitken *et al.* 1984; Campbell *et al.* 1983).



The coal ash industry has a well-defined scope to promote to practitioners the use of their products. Market development is well advanced with regulatory considerations, commercial implications, ash selections and application options for use of fly ash under Australian conditions (Yunusa *et al.* 2012). Table 1 highlights these aspects.

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

Table 1 Strategies for Realistic Market Opportunities

Strategy	Action
Market Identification	
1. Applied Research 2. Review	Amelioration of soil constraints – baseline aspects of (i) mitigation of soil acidity, (ii) amelioration of sodicity, (iii) nutrient supply and minimisation of nutrient loss, and (iv) amelioration of soil structural and hydrological properties
3. Materials knowledge	Investment into broader testing suites relevant to agricultural /soils applications expanding the traditional technical aspects of coal ash as a supplementary cementitious material and the environmental aspects association with characterisation of heavy metals and radioactivity. Extend this knowledge into the coal ash industry.
Advocacy and Education	
4. Environmental Regulation	Advocacy within the regulatory sphere to identify responsibilities for suppliers, processors and consumers, with the result that legal certainty can be defined.
5. Knowledge extension	Conduct an extension process, supporting publications across the scientific journals and the publication of technical literature such as by the ADAA.
6. Technical support	Support market advocacy for a coal ash industry through monitoring programs

Market Opportunities

The ADAA, through funding for their development projects, have identified that market opportunities for Australian fly ashes exist more broadly than only soil amelioration by gypsum replacement. The potential for agricultural use of fly ash covers-off four major soil problems for agricultural producers and their profits: soil acidity, soil sodicity, nutrient supply and minimisation of nutrient losses, and amelioration of soil structural and hydrological properties. Combined, these are major soil problems to plant growth and crop yield, currently costing the industry a profit of almost $3 billion annually (Yunusa *et al.* 2007). In addition to fly ashes as the solution to the suite of typical soil constraints, there are other opportunities within soils-based applications. Enhancement, capture and protection of atmospheric carbon in soil due to fly ash addition is a new area with substantial potential in the abatement of carbon emissions in agriculture (Yunusa *et al.* 2007). In this case, fly ash physically protects any organic matter that is sorbed on to mineral surfaces from microbial decomposition that would liberate carbon dioxide (Palumbo *et al*. 2004). Thus for Australia, fly ash as a soil amendment in agricultural lands also offers opportunities to improve food security and sequester carbon (Ukwattage *et al*. 2013). It is these aspects of soil management that we identify as our Australian market opportunities.

Attributes of Australian Fly Ashes

Australian fly ashes can have diverse chemical and physical properties. Their pH ranges from highly acidic to a highly alkaline with salinities non-saline, saline or sodic (Yunusa *et al.* 2007). Brown and black coals are used in Australia, black coal being the predominant fuel used to produce coal ash. Chemically composition is classified as Class F with < 10 % compositions of CaO. They are generally low in heavy metals and sulfur (Heidrich, 2005). In this context, given the unique chemical characteristics of Australian coal ash, two applied research approaches have been instigated through ADAA investment (Yunasa *et al.* 2012; Pathan (2003).

Considerations as to how these Australian fly ashes from coal combustion could be employed have formed the basis of work undertaken by Yunusa and his colleagues for the ADAA. Their work 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 summarised.

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.

Consequently, we now have a clear statement supporting a design application rate. Together with other characterisation analyses', the opportunity for proposals to use coal ash into a target soil can now be made with confidence, using these findings as a benchmark from which to develop further soil management recommendations. Coal ash material as an agricultural resource is a worthy consideration.

Commoditisation, Commercial and Legal Certainty

Alternatives for coal ash use to agriculture have required a change in context from a perceived waste to a product suited for resource recovery. In achieving its resource recovery status the coal ash materials needed to become a tradable commodity, which is based within the premise of changed perceptions in value. However, the real driver for change in Australia was the concept of legal certainty. Advocacy for a framework of legal certainty has been a priority of the World Wide Coal Combustion Products Network (Heidrich *et al*. 2013). In Australia the premise of legal certainty (Yunusa *et al.* 2006) has established the basis for commercial options for coal ash use to civil and soil based industries. These were developed through Environment Protection authorisations granting general exemptions to waste regulations (EPA NSW 2006) based on an extensive materials assessment process. In real terms these processes have defined commercial opportunity, facilitating the formation of markets within a context of fit-for-purpose materials such as matching for soils applications. This is the framework of legal certainty that will underpin all corporate, commercial decision-making processes.

Advocacy and Education

At present the ADAA membership constituency is without any commercial enterprise or representative from the agricultural landholder group. Similarly, the data provided by supplier member companies through their annual reports reflect negligible tonnage to an agricultural use (HBM Group 2012). One role for the ADAA National Technical and Education Committee of the

ADAA is to coordinate through advocacy extending to these stakeholder groups, thus integrating into a coherent whole a national objective.

The ADAA has a considerable investment in technical literature with the use of environmental monitoring reports, their CCP Handbook edition (Gurba *et al.* 2007), reference data sheets, technical notes and research literature (ADAA 2014). One milestone in the research forum is the current ADAA publication *'Coal Combustion Products Handbook'* (2007) and a forthcoming 2014 revised edition will consolidate the major agronomic benefits achievable with Australian fly ashes as understood at the time of the handbook's publication in 2007. A summary of this handbook chapter, in the form of a short reference data sheet is ready for publication by the ADAA to enable broad audience access to this information. In this example the relevant information has been made available as part of the Association's extension portfolio and commitment to market establishment.

Technical literature is also supported with data obtained through a national program of testing. Since 2010, the focus of this program has developed to include relevance to applications, for both civil and agricultural soils and is a significant investment by the ADAA into broader suites for analytical testing with more relevance to agricultural and soils application. This strategy has resulted in the expansion from traditional technical aspects of coal ash as supplementary cementitious properties, and in environmental risk (including heavy metals and radioactivity), to re-defining the selection of suitable and candidate materials on the basis of agronomic potential. Conveying information about the material properties for soils applications is central to this market identification process.

Market Character

The chemical composition and elemental structure of the alumino-silicate residue from the burning of coal for electricity generation provide many interesting opportunities for benefication. In Australia the resource recovery options include a wide range of cementitious and soil applications. These include commercial use as supplementary material in production cement; replacement material for sand, cement and aggregates in concrete products; uses in soil construction materials or as replacement soil materials; and as amendment materials for horticultural and agricultural soils. Two market opportunities for agricultural soils are the use of coal ashes to treat 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 (Ukwattage *et al.* 2013; Barson *et al.* 2012) is well documented as a zone in Western Australian, the coastal and tablelands areas of the eastern seaboard from Adelaide in South Australia and through to the mid-Queensland coast. In this case a 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 (Dolling *et al*. 2001). To service this potential, we have Australian coal ash resources intermittently dispersed within regional coal basins (Figure 1) and located within these agriculturally productive regions.

There are however logistical implications we highlight for this market and these include the broad nature of the distribution within a wide range of stakeholders, commercial interests, marketing competition and potentially a limit to supply. Here we identify that although the technical soil opportunities are well defined within the current framework for use, it will be successful management of the supply process that ultimately will build the market confidence and maintain the use of fly ash to treat acidified soils. Similarly, there is market potential across a significant land area for fly ashes with chemical properties to improve sodic soils (Yunusa *et al.* 2012). However, in

Australia whilst we do have fly ashes with low SAR values that can replace or supplement gypsum (Yunusa *et al.* 2007), field examples that demonstrate remediation of soil sodicity are lacking.

With the minimal commercial activity for coal ash local markets to agriculture there is also no commercial dollar value defined. Currently the commercial price has no other value that its comparison to conventional soil amendment products (Yunusa *et al.* 2012) or the cost of freight. Until commercial benefits can be fulfilled on-farm an appropriate value cannot be estimated. However, this value comparison is not as appropriate at it first seems. Formerly, research with Australian fly ashes has been with run-of-station raw feed products purely demonstrating the mechanism and responses in soils. These comparisons identified incorporation into topsoil is the best methodology for Class F Australian fly ashes (Yunusa *et al.* 2007) because it is the sizes of the particles which confer benefits to subsoils, with improvements in soil structure, hydrological properties, pH response and nutrient retention. However with conventional agricultural practices for fertiliser or gypsum and lime applications (storage and soil incorporation) those methods are not suited for fly ashes (Fig. 2). This is a critical consideration given most fly ash particles size range is below 10 µM and up to 200 µM, and from the generator's point of view to place these raw materials into situations where appropriate soil delivery technologies are not developed this has significant commercial risk and is a breach of current environmental regulations. Consequently, the field management of CCPs use for agriculture is a technical aspect for the industry as a whole that is not well defined. To progress market opportunities product assessment and material processing options should be undertaken.

We highlight that time frames for market establishment will extend into following decades. Time frames of ten years or longer will be needed to demonstrate the practical applications by field trials and also establish the product distribution networks. In real terms the rate of farmer acceptance will be based on the favourable outcomes from field trials as plant yields are matched to cost effectiveness, which may take several seasons or years to establish.

Figure 2. Conventional field techniques will not appropriate for materials storage and achieving soil benefits, so materials processing is a marketing option.

Summary

Markets are driven by local demand and by advocacy at a national level, both of which are subject to personal and professional understanding, which then translates to commercial opportunities. In this paper, a summary overview is presented to further the extension portfolio of knowledge as developed through scientific research, technical support and education. The advances in technical knowledge that demonstrate that coal ash as an agricultural resource remains a worthy consideration were highlighted. We now have a clear statement supporting a design application rate and a better understanding of why the CCP material needs to be incorporated into topsoil. Together with other characterisation analyses', future opportunities to use coal ash into a target soil can now be made

with confidence because the industry now has a benchmark from which to develop further soil management recommendations.

Market opportunities for coal ash to Australian agriculture lie in the industry's ability to solve nationally represented soil problems that limit productive capacities, improve food security and sequester carbon. Of the four niche capacities for coal ash applications to agriculture, the example associated with acidified soils was used to demonstrate the scope of the agricultural market, management of production and distribution networks within a unified industry approach facilitated by a nationally established supply commitment. In this context long time frames will exist for a market with development that currently has few if any examples of practical applications for coal ash use on farm. The coal ash industry is however, well represented by ADAA and the strong role in research, advocacy and education. These are important contributions in developing a unified industry commitment and support for the use of coal ashes. Next stage market developments will be logistic, establishing market confidence in the coal ash products, with continuing advocacy of policy and industry commitment over the next five to ten years.

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