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Research paper

An innovative systematic approach to internalize external costs of salinization in major irrigated systems

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ABSTRACT

Agricultural production has external costs embedded in different forms. These externalities have not yet been internalized in the market's prices. The study applied a basin-wide systematic approach to manage river salinity, which is one of the most vexatious of these externalities, and needs urgent remediation. The application of the approach is exemplarily demonstrated for the Murray Darling Basin (MDB) in Australia. An in-depth economic analysis indicates that in the upper areas, plant-based options are suitable and economically viable, while in middle and downstream parts of the MDB, more options are suitable such as irrigation management, subsurface drainage and effluent reuse, and salt interception systems and Sequential Biological Concentration (SBC). The SBC differs from most other options since it provides direct economic benefits to the operators and is profitable. We adopt Pigouvian recommendations as polluters pay principle to internalize externality. Charging salinity credits in terms of polluters pay principle (e.g. in this case of about A$53 t^{-1}) would result in attractive economic returns even at higher level of salinity, thus offering sufficient incentives to invest in relevant salinity management strategy. We recommended that potential salinity mitigation technique should consider regional characteristics and that it should be focused on high impact salinity zones to increase the effectiveness of the effort.

1. Introduction

Social and environmental externalities of agricultural production have not yet been internalized in the market's prices. This is valid for irrigation by ground- and surface waters, which results in salinization of soils and river water observed in many parts of the world (Pitman and Läuchli, 2002). The corresponding high external costs of agricultural production using irrigation require effective strategies to mitigate river salinization. On global scale, several salinity mitigation techniques have been developed and each of these has had some success in reducing discharge. However, while each has its own strengths and weaknesses, they are developed to manage specific types of salinity (Kijne et al., 1988).

One of the most concerning aspects of salinity is that it not only affects the immediate area of an irrigated property but also in the downstream areas, creating negative externalities (Hillel, 2000; Greiner and Cacho, 2001; Hajkowicz and Young, 2005). The externalities exist in situations where the activity of one person affects or spills over onto another, without the latter person receiving compensation (Baumol and Oates, 1993). In many irrigation areas, the excess drainage water containing salt and other pollutants is either directly discharged to rivers or recharges the underlying and adjacent aquifers. In both cases, either downstream irrigators or other parties using water from the river are affected.

The negative externality presents a market failure because the downstream water users are not compensated for the damage caused by higher salt levels. The water users in the upstream area do not internalize the cost of disposing drainage water, as there is no signal to the water user in the form of water price or other regulatory mechanism. Market failure often has its roots in poorly defined property rights, causing overexploitation of the resource. Market failure in resource management may be overcome by applying principles that define property rights.

Due to the diversity of hydrologic basins, the wide scale and the seriousness of the basins salinity problems, salinity mitigation

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Fig. 1. Murray-Darling Basin. NSW: New South Wales, NT: Northern Territory, QLD: Queensland, SA: South Australia, VIC Victoria.

demands a systematic approach. Using the Murray Darling Basin (MDB), Australia (Fig. 1), we showcase our generally valid systematic approach.

The MDB is the most significant and productive agricultural area in Australia generating around A$19.4 billion dollars or 40% of Australia's gross value of agricultural production (ABS, 2015.). However, the sustainability and productivity of the MDB is under serious threat due to waterlogging and secondary salinization of landscapes (Ghassemi et al., 1995). The salinization of the MDB has increased steadily since 1990s and the extent of this will continue to grow in the future (MDBA, 2014; Cullen, 2001; Chartres et al., 2003) since MDB is geologically and climatically prone to concentrating salt in its landscape.

Followed by reviewing previous efforts for salinity management, this paper presents a fresh appraisal of basin-wide salinity mitigation, whole of the system approach, in the MDB. To achieve this, we propose dividing the MDB into three regions, the upper part – dry-land areas/non-irrigated areas, the middle part – irrigated areas, and downstream areas – lower Murray. Research includes in-depth economic analysis of different salinization technologies for our basin-wide salinity mitigation model including a combination of salinity mitigation techniques that could be implemented considering the regionally variable characteristics of the MDB, and salinity management and target zones to achieve the effectiveness of the effort shall be determined in general valid form.

2. Review of previous efforts for managing salinity

Several salinity mitigation techniques have been developed and promising enough to be implemented in the MDB. The following provides a review of well-known salinity mitigation techniques in the MDB, and globally.

2.1. Plant-base salinity mitigation

Plant-based salinity management schemes redress the hydrologic imbalance of catchments by reducing the recharge to groundwater that mobilizes salt to the ground surface (Clarke et al., 2002; Dowling and Dawes, 2004; Hajkowicz and Young, 2002). There are several plants, which are suitable for planting in recharge areas, including herbaceous perennials, shrubs, and trees. Similarly, in the discharge areas legumes, some grasses, and shrubs, which are salt- and waterlogging-tolerant, could be planted to manage salinity (Pannell and Ewing, 2006; Pannell et al., 2003). Lucerne crops in irrigated and dryland areas, annual and irrigated summer pastures, irrigated woodlots and trees along channels are also promising (Kuginis and Daly, 2001, Orange). The problem of revegetation is the long lead time before impacts are realized. DWLBC (2005), for example, reported that a minimum time lag of 50 years would occur before benefits can be achieved. Heaney et al. (2000) further stated that replanting of native vegetation on cleared land may fully restore the salinity balance between recharge and discharge within 100–200 years. Hill (2004) stated that the groundwater characteristics affect the economic as