Incorporating heterogeneous opportunity costs into incentive design for salinity mitigating policies in Western Australia

Sallyann Harvey[1], **Atakelty Hailu**[1], **Ben White**[1]
[1]School of Agricultural and Resource Economics, University of Western Australia

Introduction

In this paper, we develop a systematic approach to inform the design of cost-sharing agreements (CSA) for Natural Diversity Recovery Catchments (NDRC) in Western Australia. The objective is to design agreements which take into account heterogeneous opportunity costs of land and provide incentives to landholders encouraging them to undertake salinity mitigating activities. In reality, such costs are only known by the landholder and consequently are often omitted from incentive design. This would not be a problem if all landholders had the same opportunity cost of land, but the large size of catchments in Australia mean they often do not. If there is heterogeneity and such costs are not considered, the incentives offered may not induce enough landholders to participate in salinity mitigating schemes.

Current incentives in NDRCs differ from catchment to catchment, but most offer funding for native species revegetation and fencing of remnant vegetation based on the Beneficiary Pays Principle of cost-sharing. Rather than individually negotiating the ratio of benefits to the natural asset and on-farm benefits, the Lake Warden NDRC (LWNDRC) has streamlined this process by establishing different payments for the same actions between priority zones. The priority zones are ordered according to impact on the Lake Warden Wetland System (LWWS). No payments are made to cover thelandholders opportunity cost of taking land out of production for salinity mitigation, these costs are implicitly assumed to be borne by the landholder as part of the CSA. If landholders in the LWNDRC have varying opportunity costs of land within zones, the payments offered may not be enough toinduce the level of participation required for the protection of the LWWS.

The objectives of this paper include: 1) estimate the level of heterogeneity of opportunity costs of land for a group of farmers in the LWNDRC; 2) use the estimated opportunity costs to determine the optimal payment, under the scenario that the regulator can observe individual landholders opportunity costs of land; and 3) compare the results to the current policy of differentiating payments by impact on the natural asset in the LWNDRC and discuss implications of using such estimates for improved policy design in the realistic situation where these costs are unknown.

Materials and methods

Opportunity costs of land were derived by estimating individual profit functions for a subset of landholders (35 observations) from the LWNDRC. Data used to estimate individual profit functions included hectares of land allocated to specific farming activities recorded in a survey undertaken in the LWNDRC in 2003. Due to a lack of information on individual yields for each crop, the Heckelei and Wolff (2003) specification of the profit function using gross margins and land as a fixed resource was followed. Gross margins were derived from average variable costs for farming activities undertaken in the Esperance Sandplain agricultural region (DAFWA, 2002) and GIS soil mapping for each farm was used to determine expected yields by soil type. Because of the small sample size and incomplete data set, the profit function was estimated using the Generalised Maximum Entropy (GME) estimator, which has been shown to perform better than the traditional maximum likelihood estimator (MLE) in problems with small sample sizes (Golan et al., 1996; Oude Lansink, 1999; Fuller et. al., 2007). Also unlike the MLE, the GME estimator does not require any assumptions about the errors for the profit function.

Landholder's estimated profit functions were then used to determine the optimal level of payment required under a scenario where the regulator can observe each landholder's opportunity cost of land. A principal-agent model is used to optimise the minimum payment required to induce voluntary land a range of recharge reduction targets for the LWWS.

The objective function of the regulator takes the form of:

$$SBF = \max_{l_i} \sum_{i}^{I} \pi_i(l_i) - \left(\sum_{i}^{I} b_i \right) * \lambda \qquad (1)$$

where SBF is the social benefit function being maximised with respect to land allocation by landholder under regulation, l_i, $\pi_i(l_i)$ is landholder profit as a function of land allocation and b_i is the subsidy for land use change to each farmer. The shadow cost of these payments is λ , and subscript i represents landholders. The objective function is constrained by the recharge reduction target:

$$\sum_{i-1}^{I} \sum_{z-1}^{Z} \left(\left(E_z * l_{i,z} \right) * a_z \right) \leq X \qquad (2)$$

where the subscript z denotes the priority zone a landholder's property lies in, E_z is the excess water generated by farming activities and a_z the distribution ratio which determines the amount of excess water from landholder in zone z that ends up in the LWWS and X is the proportional recharge reduction target.

Results and discussion

Results from the estimation of the opportunity cost of land using GME estimation show that there is a level of heterogeneity in these costs (See upper left panel of Figure 1). Estimated opportunity costs of land range from \$39 - \$247 per hectare, with 3 landholders having a zero value for their opportunity cost of land.

It can be seen in the upper right panel and both lower panels of Figure 1 that the opportunity costs of land estimated for the subset of LWNDRC landholders varies across priority zones as well. These opportunity costs of land only consider the income that landholders could earn per hectare, and do not consider the value of landuse change per hectare to the regulator. This is incorporated into the full information scenario through the delivery ratio parameter in equation (2). Results for a policy of subsidising landuse change to achieve a 30 per cent reduction in recharge where the regulator has full information about opportunity costs of land are given below in Table 1.

Table 1 shows three things. First, that optimal subsidies and landuse change vary within priority zones 1 and 2. Second, both subsidies and landuse change in priority zone 3 do not vary between landholders. Finally, the third point to note is that there are differences in the level of subsidies per hectare and the level of landuse change between priority zones. This third point suggests that the current policy in the LWNDRC of differentiating CSA payments according to impact on the LWWS is more efficient than offering all landholders the same payments across the catchment (the standard baseline policy comparison in the face of hidden information) or individually negotiating with each landholder.

The significance of the impact of recharge from priority zone 1 on the LWWS and the variation in optimal subsidies under full information imply that it might be worth pursuing individual negotiations to secure landuse change in this zone. Properties in zone 1 are mostly small and lifestyle driven and do not undertake farming activities, such that opportunity costs of land could not be estimated for them in the way presented in this paper. Results for zone 2 indicate that landholders in this zone fall into two groups, those that need a payment between \$22 - \$33 and those who need less than \$10 to induce landuse change. Rather than engage individually or offer a flat rate across the zone, two different types of CSA could be offered in which the landholder self-selects the CSA meant for them (Moxey et.al., 1999). The zone with the least impact on the LWWS, zone 3, requires the least amount of landuse change to meet the 30% recharge reduction target. Landholders in this zone make the same changes for the same subsidy (with the exception of observation 2) indicating a uniform subsidy in zone 3 may be an appropriate policy.

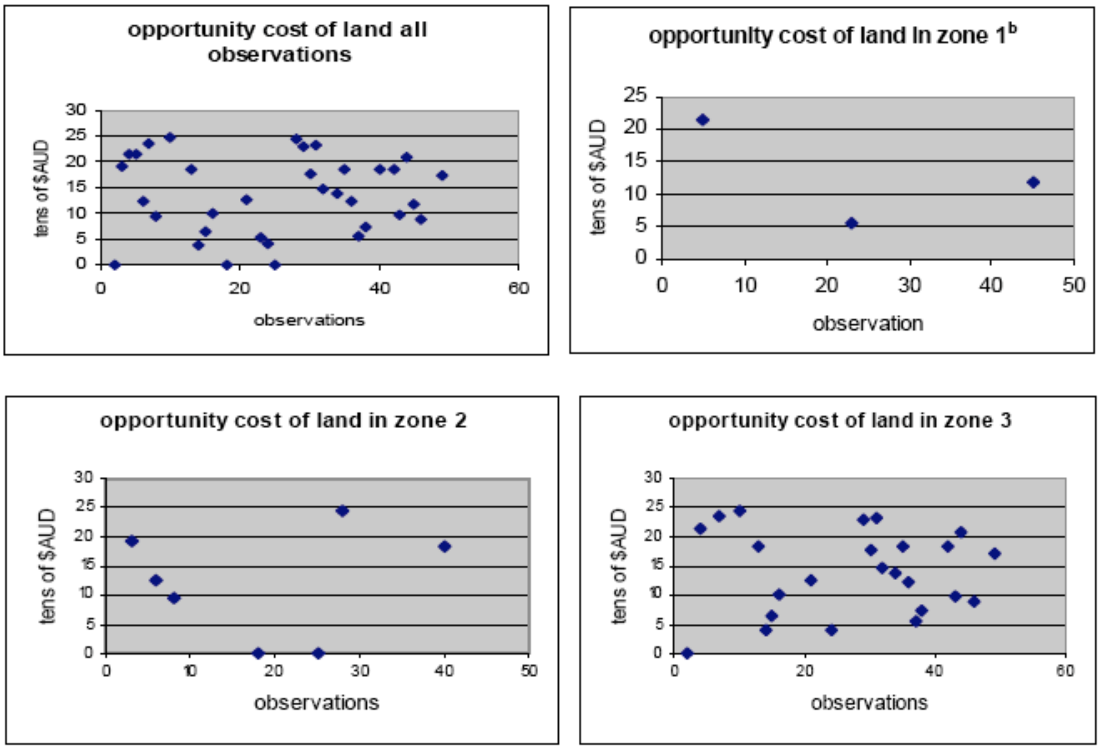

Figure 1 Estimated opportunity cost of land for LWNDRC landholders by zonea

Note: a Enterprises used to estimate opportunity cost of land were cereals, annual and perennial pastures. **b** There are 4 priority zones in the LWNDRC, zone 1 in this paper combined of observations from priority zones 1 and 2 from the LWNDRC for simplification, therefore zone 2 and 3 in this paper represents landholders in zone 3 and 4 in LWNDRC respectively.

Conclusions

Estimates of the opportunity costs of land for a group of farmers in the LWNDRC show a level of heterogeneity that indicate uniform payments for landuse change across the catchment would be inefficient. Results from the simulation of a policy to subsidise landuse change to achieve a 30% reduction in recharge when the regulator has full information showed that optimal payments differedbetween the three priority zones in the LWNDRC. These results support the differentiation of CSA between priority zones currently being undertaken in the LWNDRC; however, variation within priority zones 1 and 2 indicate that there may be benefits from further differentiation based on opportunity costs of land.

Acknowledgments

I would like to gratefully acknowledge funding provided by the CRC for Plant-Based Management of Dryland Salinity and data and advice provided by the Department of Environment and Conservation (Western Australia) and the Department of Agriculture and Food (Western Australia).

References

Department of Agriculture Western Australia (DAWA) (2002) *Gross Margins Guide 2003 Western Australia*, unpublished.

Fuller, F., Beghin, J. and Rozelle, S. (2007) Consumption of dairy products in urban China: results from Beijing, Shanghai and Guangzhou *The Australian Journal of Agricultural and Resource Economics*, Volume 51, pp. 459-474.

Golan, A., Judge, G. and Miller, D. (1996) *Maximum Entropy Econometrics*, John Wiley and Sons, Chichester.

Heckelei, T. and Wolff, H. (2003) Estimation of constrained optimisation models for agricultural supply analysis based on generalised maximum entropy *European Review of Agricultural Economics* Vol 30(1) pp. 27-50.

Moxey, A., White, B. and Ozanne, A. (1999) "Efficient Contract Design for Agri-

environmental Policy" *Journal of Agricultural Economics*, Volume 50, pp. 187 – 202.
Oude Lansink, A. (1999) Generalised maximum entropy estimation and heterogeneous technologies *European Review of Agricultural Economics* Vol 26(1) pp. 101-115

Table 1 Payment and landuse change required for 30 per cent reduction in recharge for LWWS with full information on opportunity costs of land

Obs	Zone	Change in annual (ha)	Change in kikuyu (ha)	Change in cereal (ha)	Change in unused (ha)	Transfer payment ($)	$ Payment per ha change
5	1	4.07	-0.47	-27.96	24.36	6250.80	109.94
23	1	-26.88	-0.16	-13.72	40.76	2849.06	34.95
45	1	-4.96	-0.01	-4.00	8.96	1064.59	59.40
3	2	9.34	-0.17	-9.16	0.00	469.02	25.12
6	2	9.34	-0.17	-9.16	0.00	469.02	25.12
8	2	3.51	-0.07	-6.86	3.43	462.72	33.36
18	2	-27.14	-0.21	-17.55	44.89	509.61	5.68
25	2	-22.44	-0.08	-10.28	32.79	509.61	7.77
28	2	9.34	-0.17	-9.16	0.00	469.02	25.12
40	2	7.95	-0.10	-7.85	0.00	349.94	22.01
2	3	-14.63	-0.21	-16.32	31.15	43.95	0.71
4	3	2.33	-0.04	-2.29	0.00	29.31	6.28
7	3	2.33	-0.04	-2.29	0.00	29.31	6.28
10	3	2.33	-0.04	-2.29	0.00	29.31	6.28
13	3	2.33	-0.04	-2.29	0.00	29.31	6.28
14	3	2.33	-0.04	-2.29	0.00	29.31	6.28
15	3	2.33	-0.04	-2.29	0.00	29.31	6.28
16	3	2.33	-0.04	-2.29	0.00	29.31	6.28
21	3	2.33	-0.04	-2.29	0.00	29.31	6.28
24	3	2.33	-0.04	-2.29	0.00	29.31	6.28
29	3	2.33	-0.04	-2.29	0.00	29.31	6.28
30	3	2.33	-0.04	-2.29	0.00	29.31	6.28
31	3	2.33	-0.04	-2.29	0.00	29.31	6.28
32	3	2.33	-0.04	-2.29	0.00	29.31	6.28
34	3	2.33	-0.04	-2.29	0.00	29.31	6.28
35	3	2.33	-0.04	-2.29	0.00	29.31	6.28
36	3	2.33	-0.04	-2.29	0.00	29.31	6.28
37	3	2.33	-0.04	-2.29	0.00	29.31	6.28
38	3	2.33	-0.04	-2.29	0.00	29.31	6.28
42	3	2.33	-0.04	-2.29	0.00	29.31	6.28
43	3	2.33	-0.04	-2.29	0.00	29.31	6.28
44	3	2.33	-0.04	-2.29	0.00	29.31	6.28
46	3	2.06	0.00	-2.06	0.00	26.53	6.45
49	3	2.33	-0.04	-2.29	0.00	29.31	6.28