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Exit Timing Decisions under Land Speculation and Resource Scarcity in Agriculture

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Abstract

This paper explores the concept of agricultural resilience in the context of climate change related water scarcity. Specifically, the impact of water scarcity on agricultural production is analyzed to derive the timing of exit decisions for farmers faced with the prospect of declining profitability in agriculture but increasing benefits from land rezoning in future. The prospects of land rezoning are modeled as a poisson process which may or may not be influenced by farmer's water abstraction decisions. Selling out of agriculture before land rezoning has an impatience cost as the farmer does not gain the maximum speculative rewards. The analysis highlights the role of such speculative rewards in making farmers resilient to declining profitability in agriculture and also identifies the circumstances under which the water prices may be an ineffective policy tool for allocating water. An empirical application is performed using the above model for the case of a drought prone region in Western Australia.

Keywords: agricultural resilience, exit timing, water scarcity, climate change

1. Introduction

Climate change related water scarcity is increasingly becoming a harsh reality for many countries. While water has several competing uses, agriculture has been the main beneficiary of water recourses historically. Increasing frequency of droughts, however, has forced water usage restrictions on farmers, thereby imposing declining profitability in agriculture. Yet, farmers have been found to be resilient to such climatic impacts (Keil *et al.* 2007).

Several theories have been proposed to explain farming decisions under external pressures. Farmers' timing of entry and exit decisions has received considerable attention in the agricultural economics literature. Previous literatures have found links of exit decisions with farm characteristics, farmer's age (specifically retirement and pre-retirement decisions) and the existence of potential successors (see e.g. Kimhi 1994; Pietola *et al.* 2003).

Urbanization pressure has been studied as well. For farmers to survive rapidly rising land value from urbanization, two recommendations have been made by Adelaja *et al.* (1998). First, farmers must switch to high value crops that yield more profitability (e.g, ornamentals, herbals and vegetables). Second, institutional changes are necessary so as to protect farmers via mechanisms such as farm land preservation or right-to-farm acts.

Declining profitability within agriculture has caused farmers to take to speculative measures. Speculative effects and reliance of farmers on capital gains from farmland sales compromises the long-term competitiveness of farms as farmers are reluctant to invest in new technology, or so called "impermanence syndrome"(Lockeretz, 1989). With prospects of selling farm lands to urban developers, farmers perceive their lands as a financial asset instead of a

productive input (Lopez *et al.*, 1988) and prefer to operate at sub-optimal efficiency and wait-it-out until land is rezoned to urbanization.

There exists an extensive literature devoted to understanding the linkages between land speculation from urbanization in the rural areas on efficient farming practices (see e.g. Raup, 1975; Plaut 1980; Lopez *et al.*, 1988; Lockeretz, 1986, 1988, 1989; Lockeretz *et al.* 1987). Kottke (1966) explains the linkages that farm business life cycle and urbanization have on timing of exit decision. However, to the authors' knowledge, none have formally linked urbanization pressure coupled with water scarcity to exit decisions.

The contribution of this paper is therefore to model the timing of farmers' exit decisions under pressure from urbanization and water scarcity in the context of depleting groundwater resources due to climate change. This paper models the farmer's decision as a binary choice problem where the farmer is forced to consider the timing of making an exit out of agriculture due to either declining profitability or higher rewards from land rezoning, from rural into urban areas. As long as the farmer decides to stay on in agriculture he optimizes over the use of water and other resources in order to reap maximum possible benefits from agriculture. The farmer's use of water resources may or may not have an influence over the possibility and timing of land rezoning. For instance, if water has more important competing uses (such as urban demand or environmental requirements), the government may decide to rezone earlier if the rate of water drawdown in agriculture is significant. When the farmer(s) can collectively influence (say through a manager of an irrigation district) such rezoning possibilities, inefficient uses of water, even though costly, might be promoted due to their impact on rezoning possibilities. Whether or not the possibilities of land rezoning are endogenized, the farmer has the option of selling land out of agriculture to another farmer or a speculative urban developer. However, this option leads

to a lower reward than the reward from waiting until the land has been rezoned. The timing of exit is determined by the intersection of the value function from staying on in agriculture (which involves profits from agriculture and expected rewards from rezoning) and the one-off reward from selling out of agriculture.

Our findings highlight the role of speculative impact from rezoning in highlighting farmer resilience in the presence of increasing water scarcity. The model is applied to the case of a water challenged region in Western Australia, the city of Perth. The empirical analysis also reveals that because the benefits from urban are so large, use of water prices as a tool for allocating scarce water resources may not be an effective policy tool when risk of rezoning is endogenous.

1.2. Model

Understanding resilience in agriculture is significant for policy purposes. Resilience has been traditionally defined in two senses; one called the engineering definition refers to the rate at which a system can revert back to its original state after an initial perturbation (Pimm1984); the other called ecological resilience refers to the amount of shock that any system can withstand before flipping into a new state (Holling and Meffe 1996). Economic resilience for agriculture can be defined as the amount of water shortage related economic loss that it can tolerate before either relocating or shutting down. Alternatively, it could also be measured in terms of the maximum amount of reduction in water supply that leaves the farming profits unaltered. This, of course, would require farmers to adapt to new water saving technologies. If farmers undergo losses, and yet do not alter farming practices or are not willing to relocate, then this could possibly be due to behavioral resilience borne out of psychological, social or speculative factors.

In this paper we use the term resilience to identify farmer's persistence in agriculture despite water restrictions and declining possibilities.

Let the output in agriculture be defined by the following production function:

$$(1) \quad q(t) = Ah(t)^\theta k(t)^{1-\theta}$$

where $q(t)$ is the output or yield at time t , A is an exogenous technology parameter, $h(t)$ is water abstraction, $k(t)$ is the use of other factors such as capital, land and labor, and θ is the share of water in output.

While agriculture may use both surface and groundwater, here we assume that only groundwater is available for farming. Let the long term water supply to agriculture be modeled as:

$$(2) \quad \dot{w}(t) = -\alpha + \beta(\text{rain}(t)) - h(t)$$

where α is the long term rate of decline of water table due to climate change, β is the amount that gets recharged through rainfall (rain), $h(t)$ is the annual harvest or water abstraction rate and $w(t)$ is the total stock of water.

Consider that the farmer maximizes long term discounted net benefits from agriculture as:

$$(3) \quad \int_0^{\infty} (pq - (w_0 - w(t))^{ch*h} - (ck)k^r) e^{-rt} dt,$$

Where p is the price of agricultural commodity, ch is cost of harvest parameter (e.g. pumping costs), ck & γ are cost of capital parameters, w_0 is the initial level of water table and r is the rate of discount. We ignore the time argument for simplicity of presentation. Farming decisions also involve long term planning in terms profitability out side of agriculture. There is an element of

uncertainty in terms of future land use allocations. Hence, even though water scarcity increases, there is an expectation that future profits from higher land prices might balance current losses. To model this we assume that the possibility of land rezoning is given by a hazard rate $\dot{\zeta}(w(t))$ of land conversion which is a function of the level of water in the mound. The methodology used for modeling the risk of rezoning in this model is based on previous works of Clarke and Reed (1994), and Tsur and Zemel (2004). The risk of rezoning is modeled using a survival function to represent the farmer's likelihood of surviving conversion into each time period, t . Let T be the moment of conversion. The cumulative probability distribution associated with conversion is denoted $F(t)$, where $F(t) = \Pr(T < t)$. The survival function captures the probability that conversion has not yet occurred in time t , and represents the upper tail of the cumulative probability distribution:

$$(4) \quad S(t) = \Pr(T \geq t) = 1 - F(t).$$

In each time period it is assumed that, conditional upon arriving in time t without yet having been converted, the system faces a certain probability of transition into the post-conversion state, denoted $\dot{\zeta}(t)$. This conditional probability, $\dot{\zeta}(t)$, is also referred to as the hazard rate.

The idea is that as the groundwater level drops, government would be forced to relocate agricultural farmers into some other areas. This would mean land resale and possible urbanization of the existing agricultural area, thus leading to very high profits from land sales. When this happens, the value function to the farmers is a one-time benefit that accrues at the time of sale. The revised objective function can now be derived as:

$$(5) \quad \int_0^{\infty} \left\{ (p(Ah^{\theta}k^{1-\theta}) - (w_0 - w)^{ch*h} - (ck)k^r) e^{-\xi} + N\dot{\xi}e^{-\xi} \right\} e^{-rt} dt,$$

where N is the speculative gain from selling their land. The objective function is maximized subject to constraints (1) and (2) and the equation of motion for the hazard rate, which is given as:

$$(6) \quad \dot{\xi} = \vartheta h$$

The hazard rate of conversion is a function of the amount of water abstracted by the representative farmer in each period (which translates into net impact on the water table over time), thus making the risk of rezoning endogenous. In reality, the risk of rezoning may be exogenous and we consider such situations later on. The current value Hamiltonian is given as:

$$(7) \quad (p(Ah^{\theta}k^{1-\theta}) - (w_0 - w)^{ch*h} - (ck)k^r) e^{-\xi} + N\dot{\xi}e^{-\xi} + \gamma_1(-\alpha + \beta(rain) - h) + \gamma_2\vartheta h$$

where γ_1 is the shadow price of water and γ_2 is the shadow price of cumulative risk of conversion. The first order condition with respect to water harvest implies:

$$(9) \quad e^{-\xi} ((w_0 - w)^{c_h*h-1} c_h * h + \theta p A h^{\theta-1} k^{1-\theta}) + \gamma_2 \vartheta = \gamma_1$$

No-arbitrage condition for the shadow price of water implies:

$$(10) \quad e^{-\xi} (w_0 - w)^{c_h*h} + \gamma_1 r = \dot{\gamma}_1$$

No-arbitrage condition for the shadow price of risk implies:

$$(11) \quad (p(Ah^{\theta}k^{1-\theta}) - (w_0 - w)^{ch*h} - (ck)k^r + N\dot{\xi}) e^{-\xi} + \gamma_2 r = \dot{\gamma}_2$$

In steady state, we get from equation (11):

$$(12) \quad -\frac{(p(Ah^\theta k^{1-\theta}) - (w_0 - w)^{ch^*h} - (ck)k^r + N\dot{\zeta})e^{-\xi}}{r} = \gamma_2$$

Steady state for equation (10) implies:

$$(13) \quad \frac{-c_h^* h(w_0 - w)^{c_h^*h-1}}{r} = \gamma_1$$

Equation (12) dictates that optimal shadow price of risk from rezoning must equal the discounted net sum of per period expected benefits arising out of staying in agriculture or rezoning. Equation (13) dictates that the shadow price of water must equal the discounted value of increased costs of abstraction from drawing an additional unit of water out of the ground. Equations (9)-(11) lay out an optimal water harvesting plan for the farmer when faced with land rezoning possibilities. However, so far, we have only considered the tradeoffs between farming and speculative benefits from urbanization which the farmer may or may not be able to influence. But, the farmer also has the option of moving out of agriculture and selling off his land to another speculative buyer at a lower price than what he would have received had the land been rezoned. We extend this binary choice of exit or not exit in the next section.

1.3. Exit Timing under Endogenous and Exogenous Rezoning Risks: A Binary Choice Extension

The revised objective function can now be derived as:

$$(14) \quad \int_0^\infty \left\{ \{pq - p_w h + N_a \dot{\zeta} e^{-\xi}\} (1 - sell(t)) + \{sell(t) N_b\} \right\} e^{-rt} dt,$$

where $sell(t)$ is 1 when the land is sold and 0 otherwise, p_w is the price of water imposed by the policy maker pq is gross profit from production function in (14), N_a is the gain from selling land after rezoning and N_b is the speculative gain from selling land before rezoning.

The above formulation allows for exiting out agriculture even as $N_b < N_a$. Once the farmer decides to exit out of agriculture he derives a one-off reward N_b and the game is over. We apply the above model to the Gnamagara Mound case, an agricultural region located on top of deep aquifer in the city of Perth in Western Australia. The aquifer was regarded as an infinite resource in the past. Climate change has caused its water table to decline over time, thereby creating conflicts between the competing uses of its water that span, urban, environmental and agricultural uses. In section 2.1 below we provide some more context to the region and its problems and then apply the above model to evaluate farming resilience and policy options.

2.1. The Gnamagara Mound

The Gnamagara Mound is a system of four loosely connected aquifers located beneath the Swan Coastal plane in Western Australia. It is the most valuable source of fresh water in the Perth Region as it provides the majority of water used for consumptive purposes in the urban area and supports the agricultural and commercial sector. The ongoing decline in recharge of groundwater through reduced rainfall from climate change and unsustainable abstraction have led to concerns that groundwater under the Gnamagara Mound is no longer a boundless source of water. Water scarcity could have significant impact on the viability of agriculture and other water dependent sectors. Optimal allocation of water between different sectors might require curtailing of water to certain sectors, particularly those with lower economic benefit from each megalitre (ML) of water consumed.

The horticulture sector on the Gnangara Mound is the second largest user of water under the mound. There is a current license to abstract 66 gigalitres of water a year or 19 percent of total abstraction (Marsden Jacob Associates, 2006)ⁱ. Although horticulture is a significant social and economic activity, under the current lower than average rainfall conditions and declining watertable levels, there is little prospect of new water licences and allocations being made available to enable new horticultural uses and land to be irrigated or for existing uses to expand (DPI, 2005). The timing of such curtailment becomes a crucial policy issue as it could determine whether or not adequate adaptation opportunities are provided to the affected sectors. Another related issue is the efficacy of such public policies. There might be significant resistance towards them which could lead to delays or inefficient uses of scarce resource if they are not adequately allocated through a market mechanism that reflects their scarcity value.

2.2. Empirical Application

We apply here in our model the Wanneroo horticultural precinct on the Gnangara Mound, which is located approximately 50 kilometres north of the city centre. The precinct has been eyed for urban development as it is strategically located close to the city and a major road (Wanneroo road) connecting the precinct and the city already exists. As Perth is experiencing exponential growth in demand for housing due to the mining boom, there is increasing interest to landbanking and speculation by property developers, investors and farmers reaching their retirement. This has contributed to non-productive use of existing rural zoned land for agriculture as farmers await for their lands to be rezoned for urban purposes.

To run empirical simulations, data on climate change impact and agricultural production function for vegetables in the Wanneroo horticultural precinct was required. The variety of

vegetables crops grown in the Wanneroo horticultural precinct generally varies from year to year depending on market demand. In this report, due to data availability, an empirical analysis of the economics of lettuce production grown using sprinkler systems was used. Data on lettuce production function was based on Brennan (2007) where a plateauing yield function with respect to harvested water (for irrigation) was specified as

$$(15) \quad q = k_0 b (g - e^{-(a+ch(t))}) - i e^{-a1h(t)} + j(m - nh(t))^2$$

Parameters and variable values in equation (15) are reported in Tables 1 and 2, respectively.

Data on recorded actual groundwater table from early 1970s to 2005 and predicted groundwater table simulated in the Perth Regional Aquifer Modeling System (PRAMS) from 2005 to 2030 was taken from the State of the Gnamara Mound Report (DOW, 2005). A represented area of the Wanneroo horticulture precinct (See Figure 2 area JP9) was chosen along with an eight year climate change scenario where the impact of climate change on the groundwater table is most severe. It was decided that an eight year climate change scenario would be most appropriate for calibrating the hazard rate as it represents the worst possible case. Figure 1 shows data points simulated by PRAMS of falling water table with time due to severe climate change impact. The lines show a fit of the data points which can be represented by the functional form:

$$(16) \quad w(t) = 41 - \eta \frac{t^{w1}}{t^{w1} + w2} - 0.1h(t)$$

where 0.1 is the conversion parameter from volume (ML) to water table height (metres). In the exogenous risk case it is assumed that the risk of rezoning is a function of the declining water table with time, due to the impact of climate change, and the increased risk is independent of

water harvesting by the farmers. The endogenous risk case includes farmers' harvest of water for agricultural production into the risk component as well. The survival probability, based on climate change and harvesting is re-specified as:

$$(17) \quad \dot{\lambda}(t) = \left\{ 1 - \frac{41 - \eta \frac{t^{w1}}{t^{w1} + w2} - 0.1h(t)}{41} \right\} p_0$$

Where p_0 is the exogenous component of the hazard rate and is used as a scaling factor for numerical simulations. While it is more likely that risk of rezoning is affected by the aggregate water abstraction of all farmers rather than a single farmer's abstraction, here we make the assumption that an individual farmer is a representative of an aggregate farmer acting on a smaller scale. Consequently, he is aware of the total impact of all individual abstractions on the risks.

Expected gain from selling land after rezoning is based on current and projected land value of urban land on Gnangara Mound. The median sales price in 2007 for the Wanneroo district was approximately \$3million/ha (REIWA, 2007). Expected gain before rezoning was approximated at half of that. Specifications from N_a and N_b are in Appendix II.

A Mixed Integer Non-linear Programming solver in GAMS was used to incorporate both continuous and binary choice controls for optimization of the above problem. We also use a 200 period time horizon to mimic a continuously lived farmer.

3. Results

We perform several numerical simulations varying the exogenous component of the hazard rate (given by p_0). A change in this parameter alters the risk of rezoning thereby changing the expected rewards from rezoning. We define the discounted sum of agricultural benefits and the expected rewards from rezoning as '*before sell*' reward and the discounted sum of one-off reward from selling out of agriculture before rezoning as '*after sell*' reward. Figure 4 compares the *before sell* and *after sell* rewards for various values of p_0 . Note that *before sell* reward is highest when p_0 is the highest and lowest when p_0 is the lowest. This should be intuitive as an increase in the overall chances of rezoning increases the expected rewards. Also, note that the *before sell* reward has a concave shape which is a result of two forces-the rising land prices pushing it upwards and the declining probability of land rezoning over time pushing it downwards. The probability of rezoning falls over time as the cumulative probability increases with time, thus making conversion far away in future less likely than earlier. The probability effect dominates the land price effect over time thus giving it the concave shape. *After sell* rewards are depicted as single point dashes in the same figure. The later the exit of the farmer, the lower is the reward from selling land. This is primarily guided by the time discounting effect. First result to note is that exit happens earlier if p_0 is lower (as given by $p_0 = 0.5$). When the chances of urbanization are slim, it is more profitable to move out of agriculture earlier, as there is no point in waiting for rezoning to happen. Also note that the reward from selling out agriculture is higher the sooner the farmer sells off. While most of the cases depicted in Figure 4 are with exogenous rezoning chances, we also consider one possibility (case with $p_0 = 1$, $p_w = 0$) where the farmer is able to influence the chances of rezoning by his choice of water usage. The logic behind this assumption is that, even though it may not be possible for a single farmer to have any significant impact on the overall water table on the Gnanagara Mound, he could still lower the water table

underneath his bore. If, all farmers have similar incentives, the risks of rezoning could be collectively influenced. Notice that the *beforesell* rewards in this endogenous case are similar to the exogenous case when $p_0 = 2$. This is primarily achieved through a very high level of water abstraction in the endogenous case. Figure 5 compares water abstraction levels for the exogenous case ($p_0 = 2$) and the endogenous case ($p_0 = 1$). Traditionally water has been available to farmers at a negligible costⁱⁱ. This is basically a case of subsidizing water for farming. A declining yield function in water discourages wasteful excessive uses into agriculture. However, our previous exercise shows that wasteful uses are still possible under perverse incentive from rezoning.

Another purpose of this exercise is to evaluate the effectiveness of market instruments as water prices in alleviating water scarcity. In the next exercise we ask, what would happen if water prices are raised significantly? Figure 6 compares the case of endogenous risk of rezoning with two water price (pw) levels- $pw=0$ and $pw=50$ (or equivalent to 50 cents per ML). In fact, we hardly find any differences in the rate of water drawdown. This is simply because the net benefits from agriculture are (including higher cost of water) are negligible as compared to speculative rewards from rezoning. Figure 6 shows the differential in the agriculture benefit function for the two cases. In order to see how the different cases have an impact on the timing of land rezoning, consider figure 7. The earliest chances of rezoning are achieved through case $p_0=2$ whereas the endogenous chances lie in the middle.

4. Conclusion

In this paper our key objective was to explore the factors and circumstances that may provide behavioral resilience to farming from climate change related water scarcity. It was determined that when risks are endogenous, water resources are highly discounted in the presence of speculative benefits from land rezoning. When risks are exogenous, the timing of exit from agriculture is influenced by the level of the risk of rezoning—the higher the risk the more beneficial it is to wait out. This provides for higher resilience under declining agricultural profits. Water pricing may not be an efficacious tool for allocating water to their most valued usage under excessive rewards from urbanization. A better policy instrument for preventing wasteful usage could be to put a cap on allowable abstraction, or water allocation limits.

While the above analysis considers only economic factors that influence exit decisions in agriculture, it does not incorporate social factors such as farmer's age and education and psychological factors such as risk aversion and risk weighting. These factors also may have a significant influence on farming decisions. Old generation farmers are less likely to move out of agriculture due to lifestyle choices compared to the younger generation. Education level may influence acceptance and adoption of new water saving technologies. Risk weighting has been found to be significant in influencing investment and speculative actions. Farmer heterogeneity may be crucial in determining resilience to droughts for a particular region as large farmers may be better able to sustain climate change related or policy shocks compared to small farmers. Inter-sectoral dynamics within the agricultural sector could also determine the level of farmer heterogeneity. Large farmers may buy out small farmers as the size of their holding may have an impact on the magnitude of their rewards from rezoning.

In a policy context, a long term approach to agricultural planning is needed to help maintain the economic viability of the agriculture sector under the increasing pressure from other

land uses such as urbanization. Adequate protection of the agricultural sector through appropriate land rezoning discourages land speculation and subdivision of land by farmers just prior to their retirement. It will also encourage farmers that choose to stay in business to adopt more efficient farming practices and water saving technologies.

ⁱ The integrated water supply system (IWSS) which provides potable water consumption to Perth metropolitan is the largest water user on the mound. The current abstraction is 344 gigalitres/year or 48% of total abstraction.

ⁱⁱ Farmers currently pay only for the cost of abstraction such as the cost of sinking a bore and the cost of electricity. It has been estimated that abstraction costs is \$50/ML or 5 cents per kilolitre (Brennan, 2007).

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Appendix I

Table 1: Agricultural Production Function and Water Table Projection

Production Function (Equation 15)	Water Table Function (Equation 16)
$a=-1.7$	$w1=3$
$a1=-.065$	$w2=49000$
$b=27000$	$H=11.7$
$c=1.56$	
$g=.305$	
$i=4500$	
$j=11.8$	
$m=18.8$	
$n=1.4$	

Appendix II

Land price specifications

$$N_a(t) = 0.7 + \frac{0.9}{e^{t+0.19}} \times 1000000$$

$$N_b(t) = 0.54 + \frac{0.35}{e^{t+0.17}} \times 1000000$$

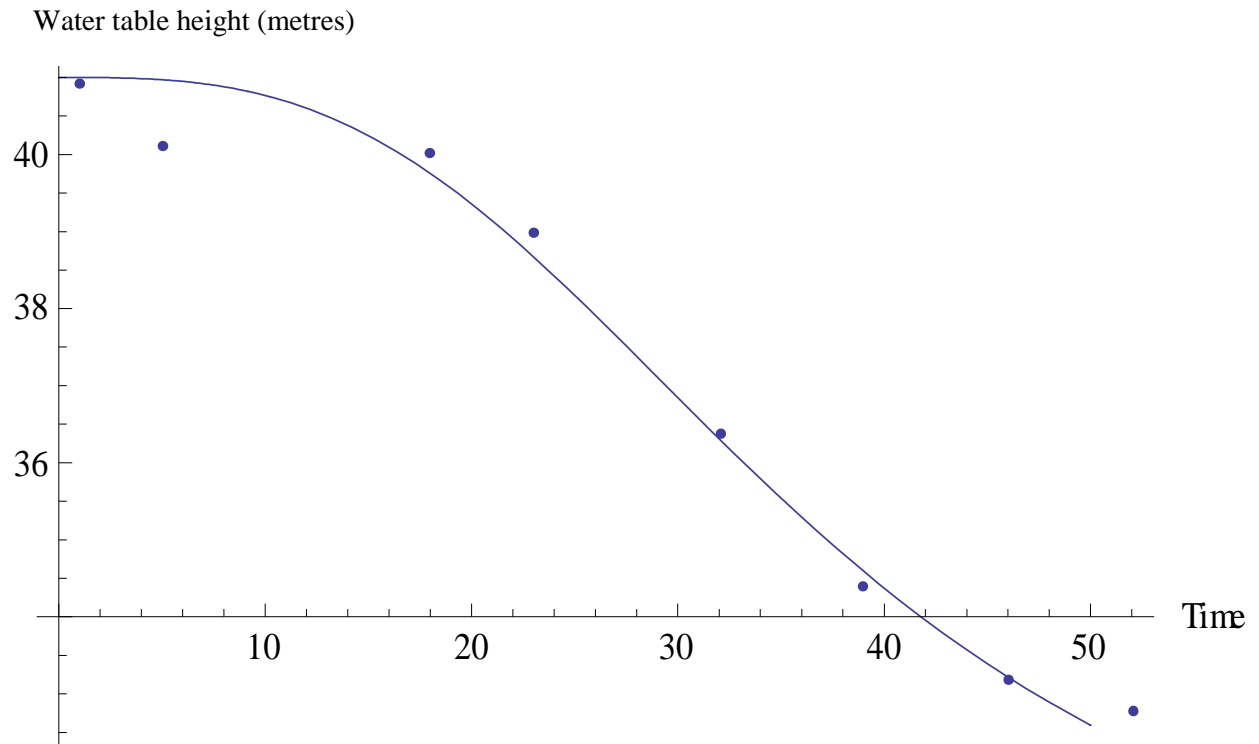


Figure 1: Projected Water Table Decline with Time (where $t=1=1980$)

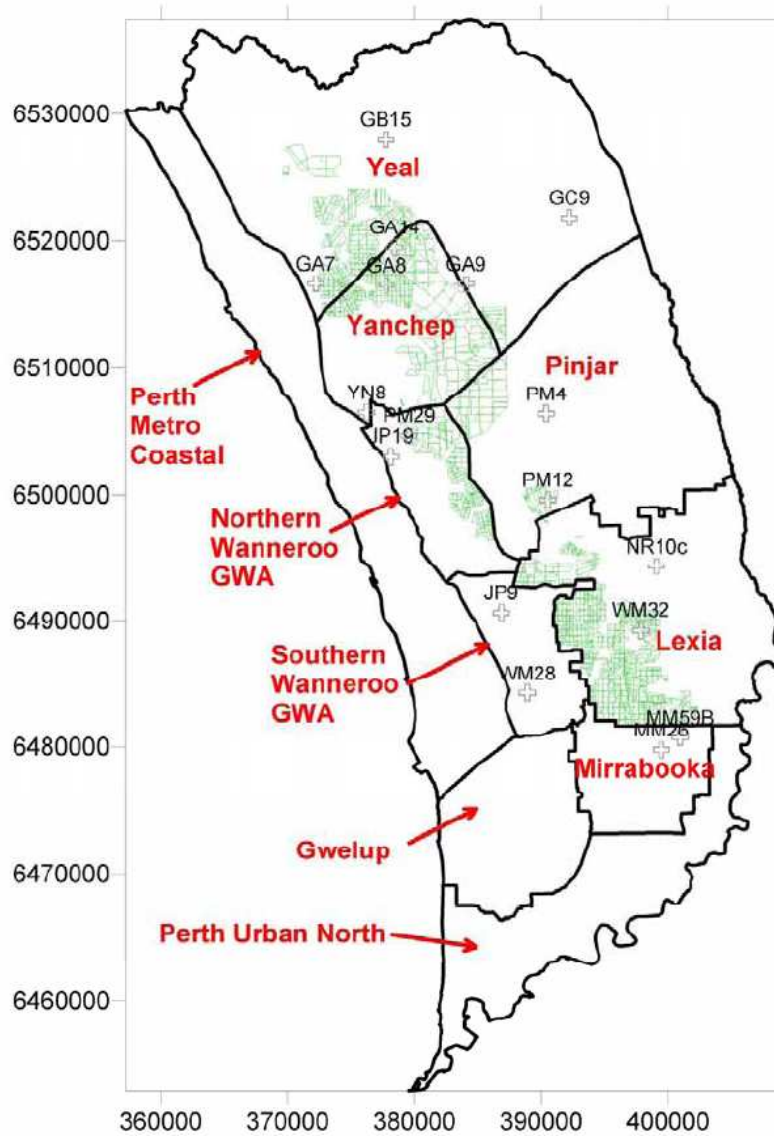


Figure 2: Gnangara Mound predictive hydrograph locations (source: DOE, 2005)

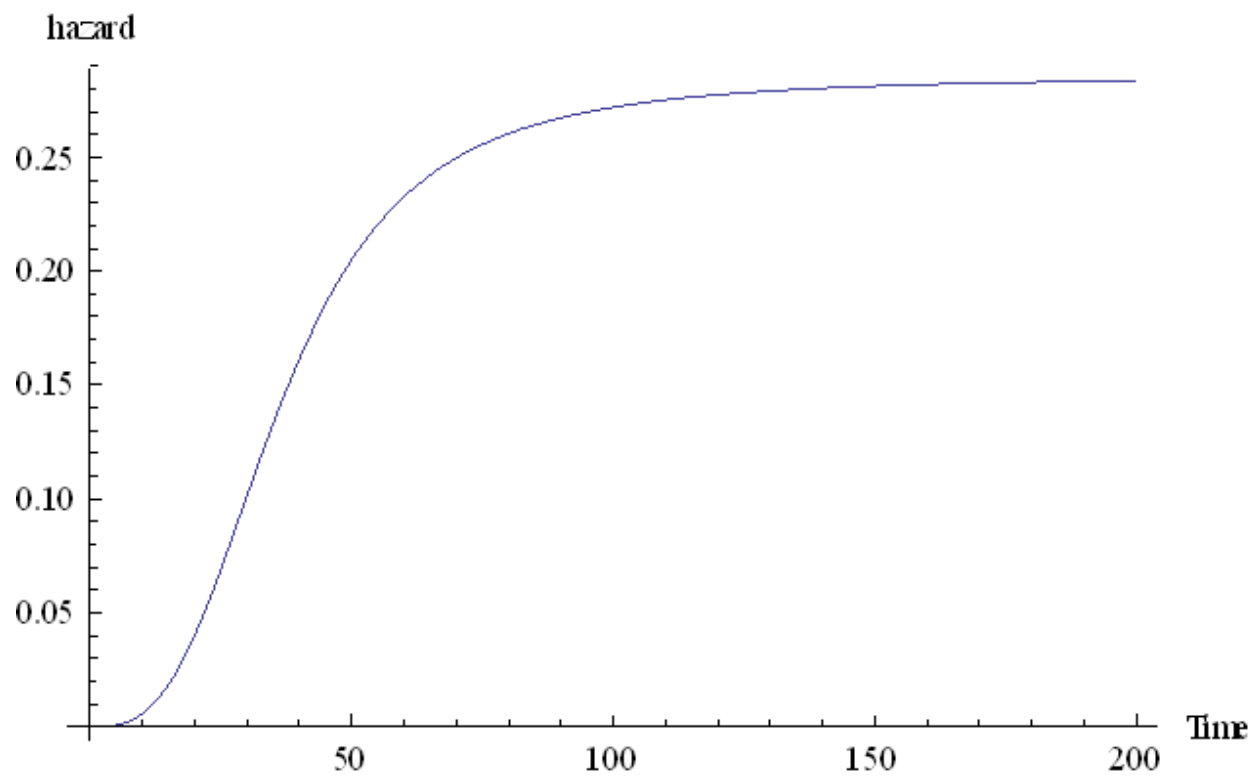


Figure 3: Survival Probability as a Function of Falling Water Table

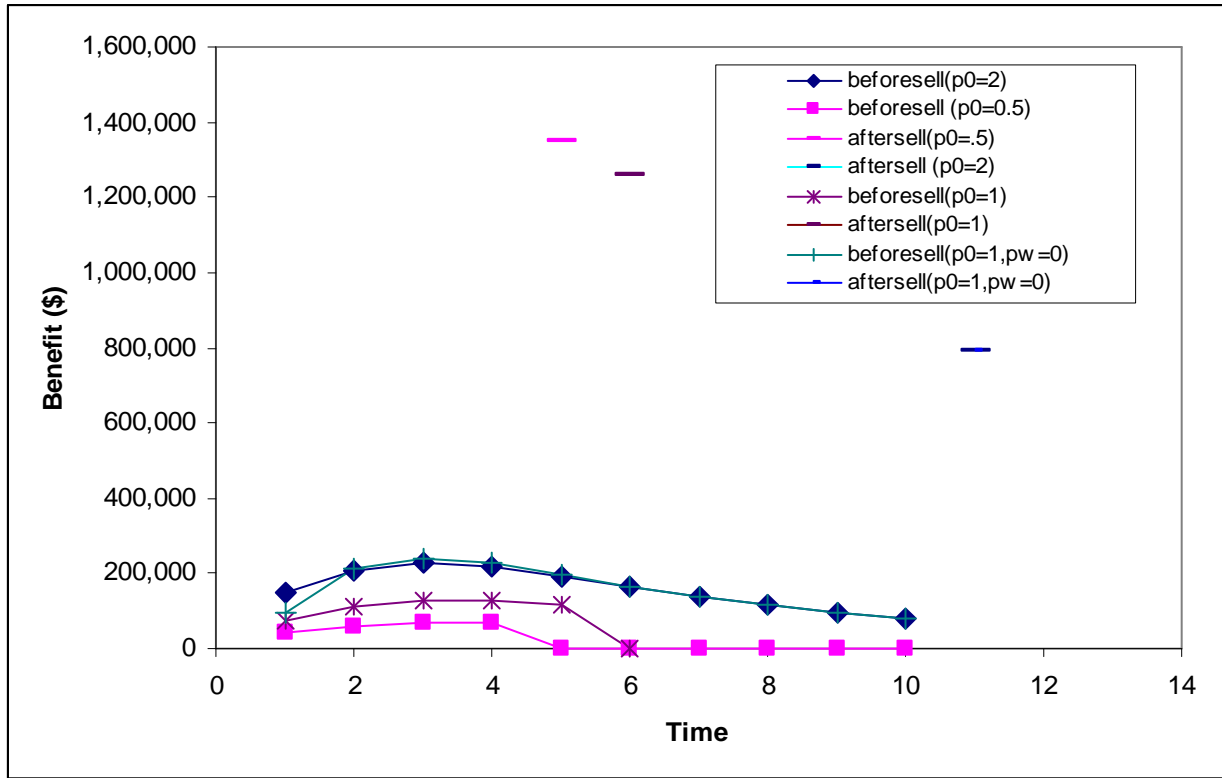


Figure 4: Before Sell and After Sell Rewards as a Function of Time

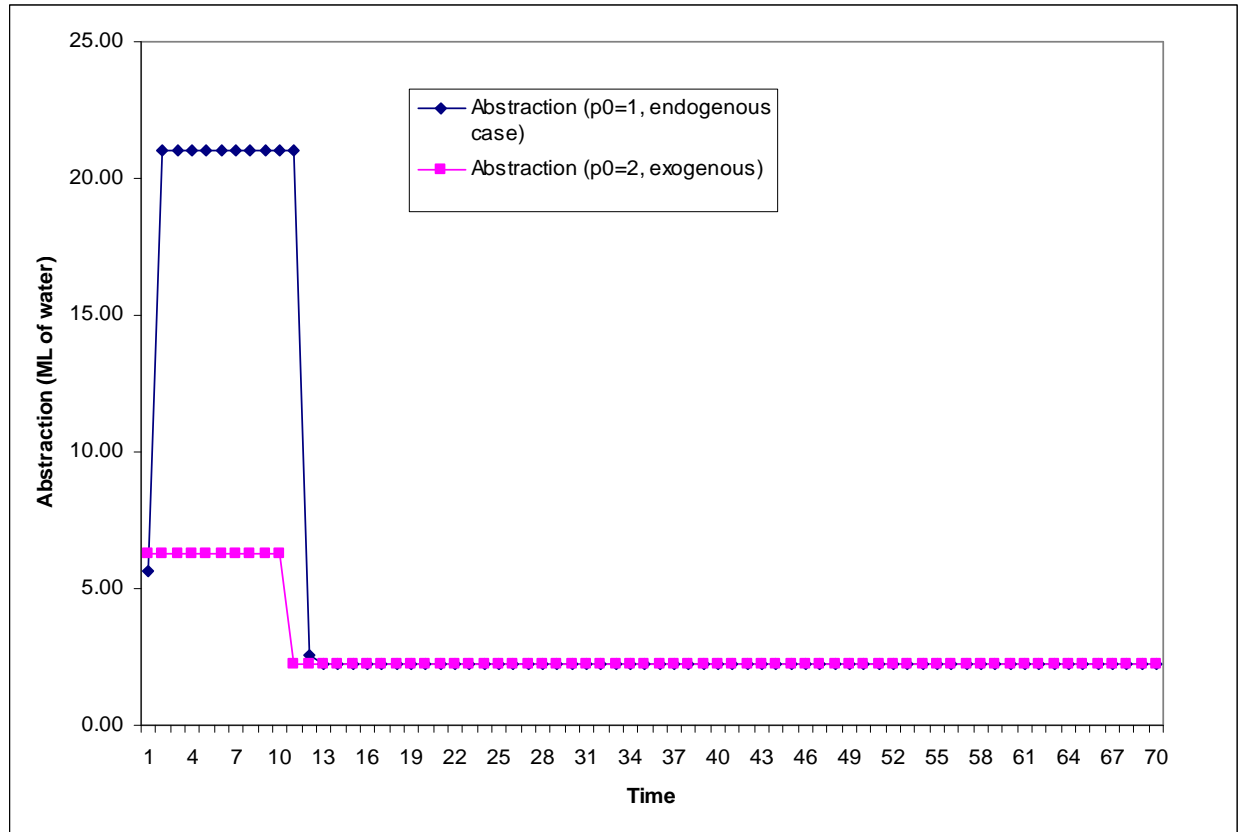


Figure 5: Water Abstraction under Exogenous and Endogenous Cases

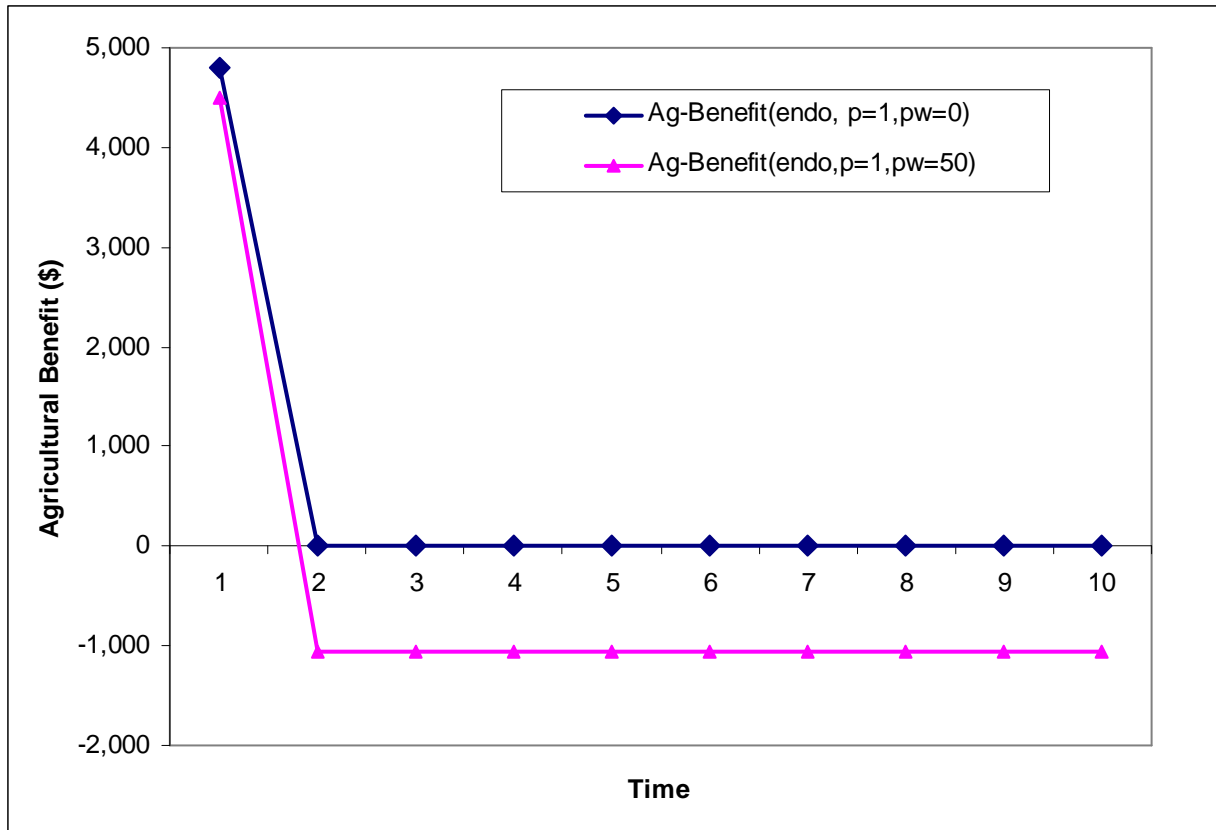


Figure 6: Agricultural Benefits under Exogenous and Endogenous cases

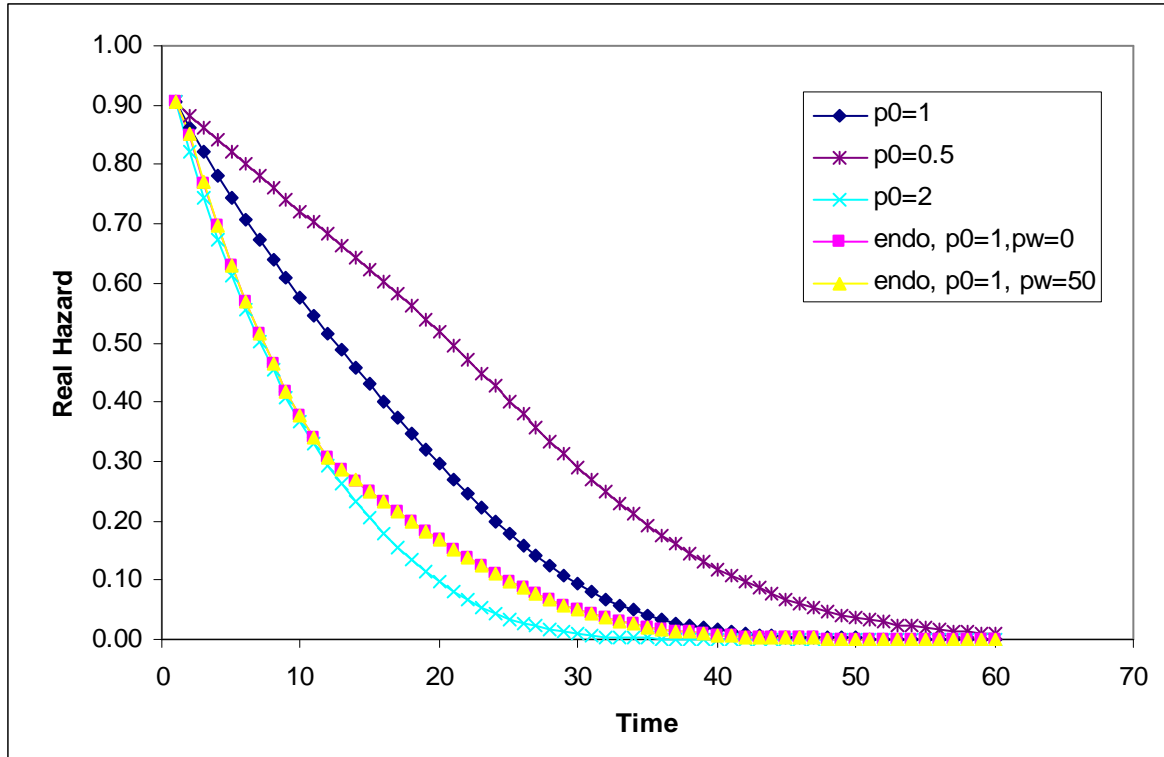


Figure 7: Probability that land will survive rezoning until time t