Appendix 1: Method of Accounting for the Impact of Frosts

The APSIM data provided did not account for frost effects. These effects were accounted for subsequently as follows:

(1) the dates of the latest frosts in each year of the historical series were obtained from R. Stone (pers. comm., CSIRO, Toowoomba, June 1995). Two dates were supplied for each year, the first relating to a frost at least as cold as 0°C and the second relating to a frost of -1°C or colder.

(2) the date of flowering in each year associated with a given variety and a given planting date was identified from the APSIM simulation data;

(3) occurrences of frost events of each of the two frost type classes on or after the flowering date, and 17 days or later than flowering, were thereby identified for each year of the historical series;

(4) in years when (a) no frost occurred on or after the flowering date, grain yield simulated using APSIM was utilised; (b) only a frost as cold as 0°C (measured in the Stevenson screen) but warmer than -1°C occurred on, or less than 17 days after, the flowering date, simulated grain yield was deflated by 40 per cent; (c) a frost at least as cold as -1°C occurred on, or less than 17 days after, the flowering date, simulated grain yield was deflated by 85 per cent; (d) a frost at least as cold as 0°C occurred 17 days or later after the flowering date, the simulated grain yield was utilised but it was assumed to be downgraded to feedgrain.

The assumed yield deflation factors for the two frost type classes were linearly interpolated from advice by D. Woodruff (pers. comm., July 1995) that grain yield loss in wheat (a) due to a frost of 0.5°C on or after the flowering date could be expected to be 10 per cent; (b) due to a frost of -0.5°C on or after the flowering date could be expected to be 40 per cent; and (c) due to a frost of -1.5°C on or after the flowering date could be expected to be 100 per cent. The assumption under 4(d) above was based on advice from D. Woodruff (pers. comm., July 1995).

Appendix 2: Method of Calculating Fixed Costs of the Wheat Enterprise

Data for average fixed costs per "small" wheat growing farm in the Western Downs/Maranoa district over 1990-91 to 1992-93 were obtained from Smith (1995b, Tables 58 and 60). These data had then to be apportioned to the wheat growing enterprise.

The proportion of depreciation on cultivation, planting, harvesting and handling plant allocated to the wheat enterprise was 100 per cent. The corresponding proportion for depreciation on motor vehicles and tractors was 80 per cent. This proportion was also used to apportion motor vehicle and tractor running expenses to the wheat enterprise. These proportions were based on estimates of the rate of utilisation of these assets in the wheat enterprise.

The corresponding proportion for depreciation on buildings and fixed improvements was 31 per cent which was the proportion of average total cash receipts for this farm type accounted for by wheat cash receipts. This proportion was the same as used in apportioning the farmer's equity in these items to the wheat enterprise (see Section 3.4). This proportion was also used in allocating cash costs other than motor vehicle and tractor running costs to the wheat enterprise. It was also used in apportioning to the wheat enterprise a share of the return of $30,000 imputed to the farm family's labour and management. Apportionment for these items according to the contribution of the wheat enterprise to cash receipts was chosen because the alternative, apportionment according to use of farm land by the wheat enterprise, would significantly under-estimate the contribution of wheat growing to fixed costs since resources in general can be expected to be used at a higher rate per hectare in cropping (of which wheat is the predominant enterprise) than in running livestock enterprises.

The fixed cost of operating the wheat enterprise was thereby estimated to be $33,395 per year (or $159 per ha available for wheat growing).

Appendix 3: Method of Calculating Option Net Payoffs

A3.1 Stage 1 Net Payoffs

The choices modelled as available to the representative farmer at stage 1 were discussed in Section 3.3. Identification of the consequence in terms of the net payoff of a particular stage 1 option given the states of nature $\{\theta_{k1}, \theta_{k2}, \theta_{k3}\}$ required (1) estimating the costs incurred as a result of undertaking the option; (2) estimating the payoff from that option subject to that trio of states; and (3) calculating the net payoff from the option by subtracting the estimated cost of the option from the estimated payoff.

A3.1.1 Cost of stage 1 options

Stage 1 options involve maintaining land in fallow and/or planting wheat crops. The costs incurred as a result of deciding to maintain a fallow were assumed to be zero. This was because (1) such an option would only be undertaken if planting conditions and/or climatic outlook were particularly poor; and (2) weed problems should be minimal in such a season.

The cost incurred as a result of deciding to plant a wheat crop was assumed to comprise the cost of land preparation and sowing and the net cost of any nitrogen fertiliser applied. The cost of land preparation and sowing was assumed to be \$48.20 per ha, as estimated in Anon. (1994).

Except for the cost of the fertiliser, it was assumed that this cost would not increase if nitrogen fertiliser were applied during sowing. The gross cost of nitrogen fertiliser was assumed to be \$1.01/kg of nitrogen, based on bulk purchase of urea @ \$445/t, \$20/t cartage to farm and a yield of 460 kg of nitrogen per tonne of urea. The net cost of nitrogen fertiliser was calculated by deducting the present value of the residual fertiliser, which is available to a crop at the start of the following season, from the gross cost. APSIM simulation data on residual nitrogen fertiliser levels at grain maturity were available for all states θ_{k3} and for all of the rates of applied nitrogen in the stage 1 decision set modelled. Twenty per cent of the residual nitrogen fertiliser at grain maturity was assumed to be available to a crop in the subsequent wheat season. The present value of this 'productive' residual fertiliser was calculated using a discount rate of 10 per cent per year.

A3.1.2 Net payoffs

The payoff from a stage 1 option associated with season *k* depends also on any 'follow-on' options that may be chosen at stages 2 and 3 and the payoffs from those options. The net payoff from a follow-on stage 2 option associated with season *k* depends in turn on any follow-on stage 3 options that may be chosen and the net payoffs from those options.

This recursive dependence had to be accounted for in calculating the payoff from a particular option taken at stage 1. This required that the follow-on options in response to θ_{k2} and θ_{k3} be identified and that their payoffs be calculated. Except for the stage 1 option of maintaining a fallow, the remaining stage 1 options require a choice at stage 2 between maintaining or grazing a crop. If the latter option is chosen, there is no follow-on stage 3 option. If the former option is chosen, however, a further choice at stage 3 is required between harvesting or grazing the crop.

The net payoff for the option of maintaining a fallow was zero, since the cost was assumed to be zero (Section A3.1.1) and the payoff is also zero. The method by which the payoff for a particular stage 1 option (excepting that of maintaining a fallow) under states of nature $\{\theta_{k1}, \theta_{k2}, \theta_{k3}\}$ was calculated using backward induction is described hereunder:

(1) At stage 3 the outcomes of all options available at that stage were assumed to be known with certainty. Of the two possible stage 3 options (ie., harvesting or

grazing) given implementation of a particular stage 1 option, the farmer was assumed to choose the one with the highest net payoff given θ_{k3}. Net payoffs of stage 3 harvesting and grazing options were calculated as described in sections A3.3 and A3.4 respectively.

(2) The stage 2 set of states is distinct from any other, so θ_{k3} represents the only relevant observation from which to anticipate the stage 3 set of states that may follow θ_{k2} in the imminent season. In the event of the stage 2 set of states θ_{k2} recurring in the imminent season, the farmer was therefore assumed to expect a recurrence of θ_{k3}. The expected net payoff for the follow-on stage 2 option of grazing the crop given implementation of the particular stage 1 option was then calculated as described in Section A3.2. The pay-off for the follow-on stage 2 option of maintaining the crop was set equal to the payoff of the stage 3 follow-on option identified under (1) as being the one that would be undertaken. The farmer was assumed to choose the stage 2 option with the highest net payoff.

(3) Since θ_{k1} is identical for all k, the farmer was assumed at stage 1 to expect values of each element in the stage 2 set of states equal to mean values calculated over all stage 2 sets of states.

The net payoff from choosing a particular a stage 1 crop planting was then calculated as follows:

(a) If step (2) indicates that the crop would be grazed at stage 2, the net payoff from the stage 1 option equals the net payoff from grazing at stage 2 minus the planting cost calculated as described in Section A3.1.1.

(b) If step (2) indicates that the crop would be maintained at stage 2 *and* if step (1) indicates that the crop would be *harvested* at stage 3, the net payoff from the stage 1 option equals the net payoff from harvesting minus the planting cost.

(c) If step (2) indicates that the crop would be maintained at stage 2 *and* if step (1) instead indicates that the crop would be *grazed* at stage 3 , the net payoff from the stage 1 option equals the net payoff from grazing at stage 3 minus the planting cost.

This sequence of conditional calculations was automated using the *IF* function available in the Excel™ spreadsheet program.

Note that step (1) above calculates the net payoff for each stage 3 option given θ_{k3}. Step (2) above calculates the net payoff for each stage 2 option given θ_{k2} and θ_{k3}.

A3.2 Net Payoff from Grazing at Stage 2

The net payoff from abandoning a crop at stage 2 and allowing it to be grazed was assumed to equal the cost saving expected to be obtained as a result of avoiding the need to use stored fodder. The assumption that stored fodder would otherwise be used was based on (1) the likelihood that a crop would only be abandoned in the event of a particularly poor season; (2) a likelihood that there would be a shortage of pasture feed in such a season; and (3) the further assumption that stored fodder would be adequate to cover this feed shortage.

The type of fodder stored was assumed to be medium quality pasture hay. The expected cost saving from avoiding the need to use stored hay was assumed to equal the cost of replacing it by producing it on-farm. The method of calculating the cost saving from a particular stage 2 'grazing option' given the stage 2 state expected at stage 1, $E(\theta_{k2})$, and the stage 3 state θ_{k3} was as follows:

(1) The additional feed becoming available to livestock as a result of deciding to graze the crop at stage 2 was calculated by (a) converting dry matter available at stage 2, non-grain dry matter expected to be available at stage 3 and dry matter expected to be available in stubble after stage 3 (if the crop were instead maintained and harvested) into common units of feed value; and (b) adding the converted values of the first two parameters and then subtracting the converted value of the third parameter. The resulting measure of feed value was then discounted by 15 per cent to account for wastage during grazing (Rickards and Passmore 1977). Note that only the non-grain component of simulated stage 3 dry matter was included since grain production would be minimal under a

grazing regime. In the event of stage 2 state θ_{k2} recurring in the imminent season, the farmer was assumed to expect a recurrence of stage 3 state θ_{k3} (for the reason given under point (1) in Section A3.1.2). Thus expected values for non-grain dry matter and stubble dry matter at stage 3 were assumed to be those represented in state θ_{k3}.

(2) Conversion factors for performing step (1) were based on feed values for succulent wheat crop vegetation and crop stubble of 1.6 and 1.2 livestock months per 100 pounds (lb) (ie., 45 kilograms (kg)) of dry matter respectively, based on data provided in Table 4.1 of Rickards and Passmore (1977). A livestock month "is defined as the energy required to maintain a 110 lb (ie., 50 kg) dry sheep grazing 'medium' quality pastures for a 30 day month, after providing an allowance amounting to 35% of the fasting metabolism for exercise" (Rickards and Passmore 1977, p. 14).

(3) The dry matter weight of medium quality pasture hay required to contribute an amount of feed equivalent in terms of livestock months to that calculated in step (1) was calculated using a conversion rate of 1.5 livestock months per 45 kgs of dry matter. The 'fresh' weight equivalent was calculated by assuming that hay is comprised of 90 per cent dry matter (Rickards and Passmore 1977, Table 4.1).

(4) The cost saving was calculated by multiplying the fresh weight of hay calculated in step (3) by an assumed on-farm hay-making and handling cost of $40 per tonne.

A3.3 Net Payoff from Grazing at Stage 3

The net payoff from abandoning a crop at stage 3 and grazing it was assumed to equal the cost saving obtained as a result of avoiding the need to use stored fodder. The method of calculating the cost saving from a particular stage 3 'grazing option' given state θ_{k3} was as follows:

(1) The additional feed becoming available to livestock as a result of deciding to graze the crop at stage 3 was calculated by (a) converting non-grain dry matter

available at stage 3, dry matter in grain available at stage 3 and dry matter available in stubble after stage 3 (if the crop were instead harvested) into units of livestock months; and (b) adding the converted values of the first two parameters and then subtracting the converted value of the third parameter. The resulting measure of feed value was discounted by 15 per cent to account for wastage during grazing.

(2) Non-grain dry matter available at stage 3 was calculated by (a) discounting dry matter at stage 2 by 40 per cent to account for leaf senescence and rotting that would occur prior to grazing after stage 3; (b) discounting additional dry matter produced between stage 2 and 3 by 10 per cent to account for similar effects over a shorter period; and (c) adding the outcomes of steps (a) and (b).

(3) Dry matter in grain at stage 3 was calculated by discounting grain yield by 12 per cent since grain yield data related to grain with 12 per cent moisture.

(4) Conversion factors for performing step (1) were again based on feed values for succulent wheat crop vegetation and crop stubble of 1.6 and 1.2 livestock months per 45 kg of dry matter respectively, as well as on a feed value for wheat grain of 2.4 livestock months per 45 kg of dry matter (Rickards and Passmore 1977, Table 4.1).

(5) Steps (3) and (4) in Section A3.2 were then undertaken.

A3.4 Net Payoff from Harvesting at Stage 3

The net payoff from harvesting a crop at stage 3 given the set of states θ_{k3} was calculated by deducting the harvesting cost from the farm-gate revenue from sale of grain.

Harvesting was assumed to be undertaken by a contractor. Charges recommended in 1995 by the Australian Grain Harvesters' Association were assumed to apply. Under this charging system a farmer is charged a minimum of $29.64/ha regardless of the yield of the crop. For each tonne in excess of a base yield of 2.47 t/ha, however, the farmer is charged an additional $29.64/ha. These charges do not cover fuel. The fuel cost per tonne of grain harvested was based on estimates in McKenzie (1994) that the speed of wheat harvesting is 0.1 hours/t and its fuel consumption is 22 litres per hour. Assuming a fuel price of $0.38 per litre, the fuel cost of harvesting was thereby estimated to be $0.84/t.

Farm-gate revenue from sale of grain was calculated by multiplying grain yield under state θ_{k3}, estimated as discussed in Section 3.5.1, by the price corresponding with the quality of the grain. Grain quality under this state was simulated as also described in Section 3.5.1. The set of prices used was calculated as follows:

(1) The average net pool return for wheat of Australian Standard White (ASW) quality (with 10 per cent protein) delivered to the Australian Wheat Board over the period 1990-91 to 1995-96 was calculated to be approximately $183/t (where the 1995-96 value used was the estimate as at 11 July 1995). Use of an average return was considered appropriate in this study given uncertainty regarding returns in future years. Deductions from this totalling $54/t were made to account for marketing costs from the farm to ship (pers. comm., R. Mercer, FarMarCo, Toowoomba, July 1995). From the resulting net farm-gate price of $129/t, the Wheat Industry Levy based on 3.03 per cent of net farm-gate price was deducted. The benchmark net farm-gate return for ASW quality wheat was thus calculated to be $125/t.

(2) Benchmark farm-gate returns for the Prime Hard (13 per cent protein), Australian Hard (11.5 per cent protein) and Feed grades of $175/t, $140/t and $80/t respectively were chosen as representative of the returns that might be expected on average in the foreseeable future. This was based on advice that it would be reasonable to expect on average a premium over ASW of $50/t for the Prime Hard grade, $15-20/t for the Australian Hard grade and a negative premium of $40/t for the Feed grade (pers. comm., M. Morison, Australian Wheat Board, Toowoomba, July 1995). For each grade other than Feed grade, an adjustment of $5 per one percentage point deviation in protein above the grade benchmark and, in the case only of ASW wheat, below the benchmark, also applied. For Prime Hard wheat, this applied to protein levels over the range 13-16 per cent. For Australian Hard wheat, the relevant protein range

was 11.5-12.9 per cent. For ASW wheat, the relevant range of protein levels was 6-11.4 per cent (pers. comm, T. Annis-Brown, Australian Wheat Board, Moree, July 1995).

The price received for a given quality of wheat grain at harvest, as calculated above, was assumed to be known with certainty by the time of a planting opportunity.

In order to use point values for wheat prices that apply for all states of nature and all forecast types it was necessary to assume that the demand for wheat is invariably perfectly price elastic. This is because in this study two sources of shifts in supply are relevant, each potentially having a price effect in the event of demand being less than perfectly price elastic. The first concerns the effect of seasonal climate on aggregate wheat industry production. The second concerns the effect of particular forecast types on farmer options and thereby on industry production.

However, in most seasons the Australian wheat price is determined in export markets where an assumption of perfectly price elastic demand is largely valid. However, in atypical seasons, such as during the drought of recent years, domestic shortages of wheat may very occasionally arise. In these instances price is set on the domestic market where the demand curve is downward-sloping. Changes in supply in these seasons could be expected to lead to a change in the wheat price received. However, such seasons are very infrequent. A judgment was therefore made that the increase in accuracy in valuing the forecasting system that would result from accounting for price effects would not be sufficient to warrant the increase in modelling complexity this would entail.

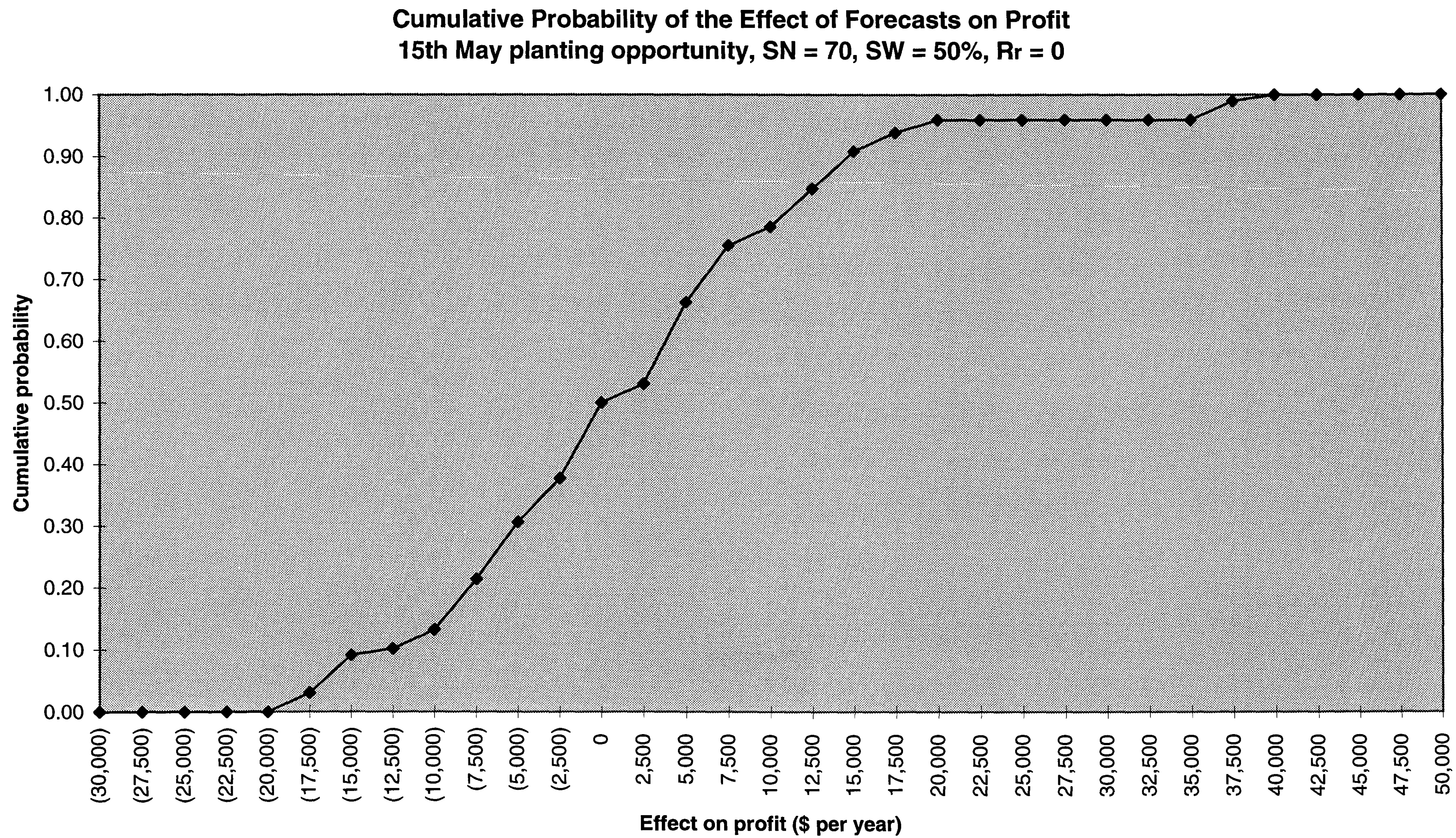
Appendix 4: Cumulative Distribution Functions for the Effect of Use of Climate Forecasts on Profit

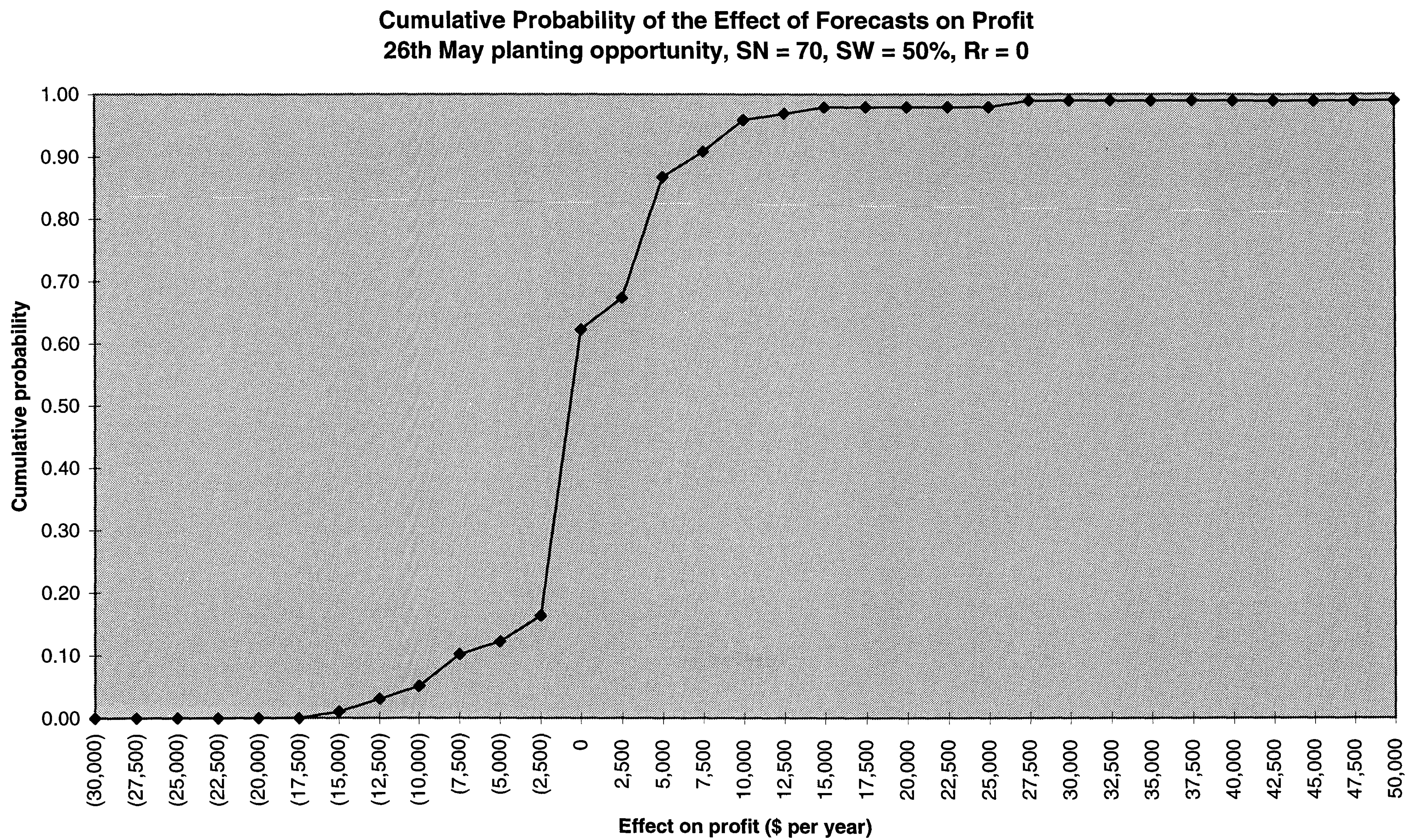
The cumulative distribution functions following relate to a risk indifferent farmer (ie., $R_r = 0$) experiencing 70 kg/ha of soil nitrogen and soil moisture of 50% of field capacity at various dates of planting opportunity.

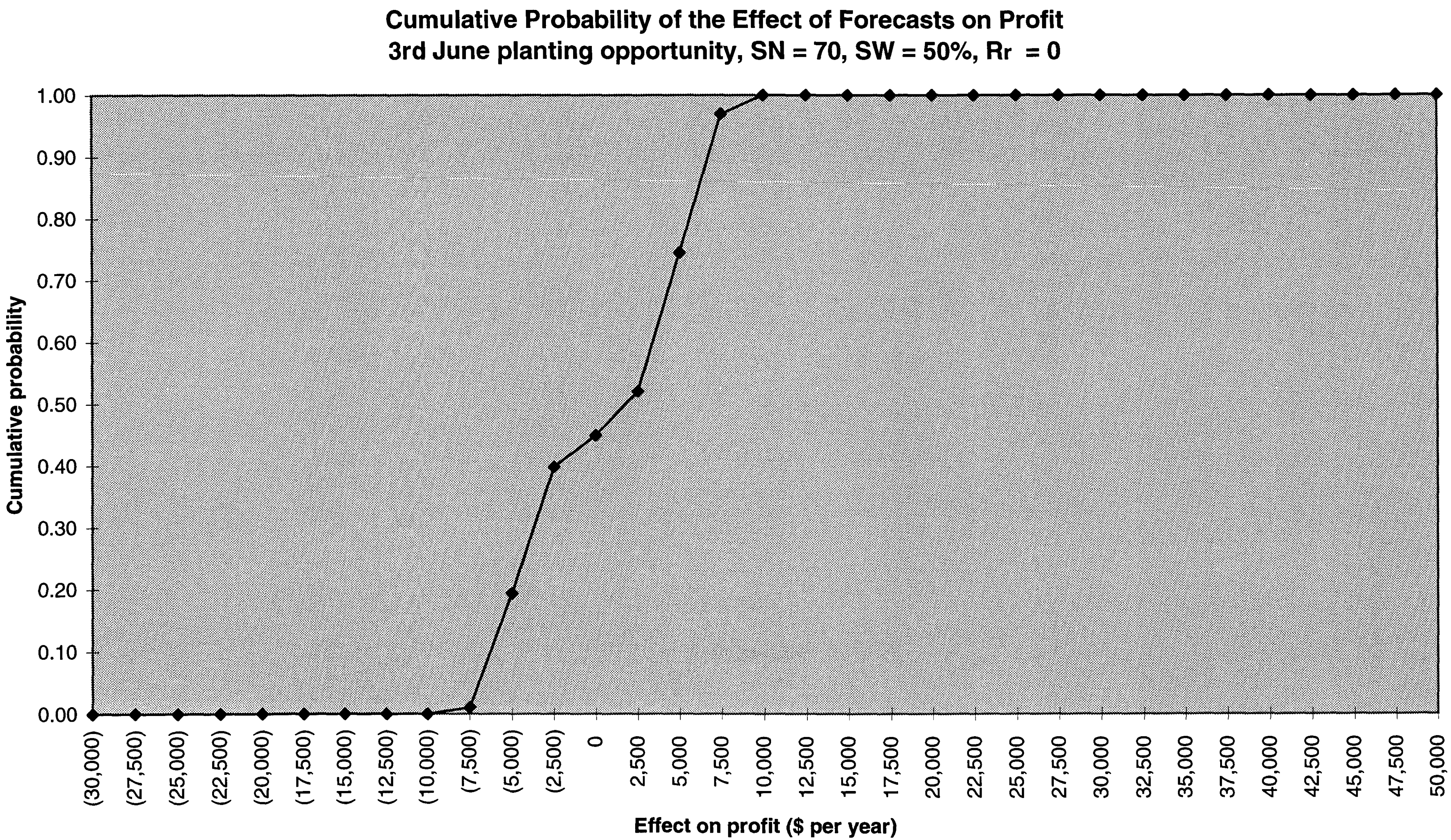
The meanings of codes used in the titles of the following figures are:

SN mineralised nitrogen in soil at planting opportunity (kg/ha)

SW moisture in soil at planting opportunity (% of field capacity)

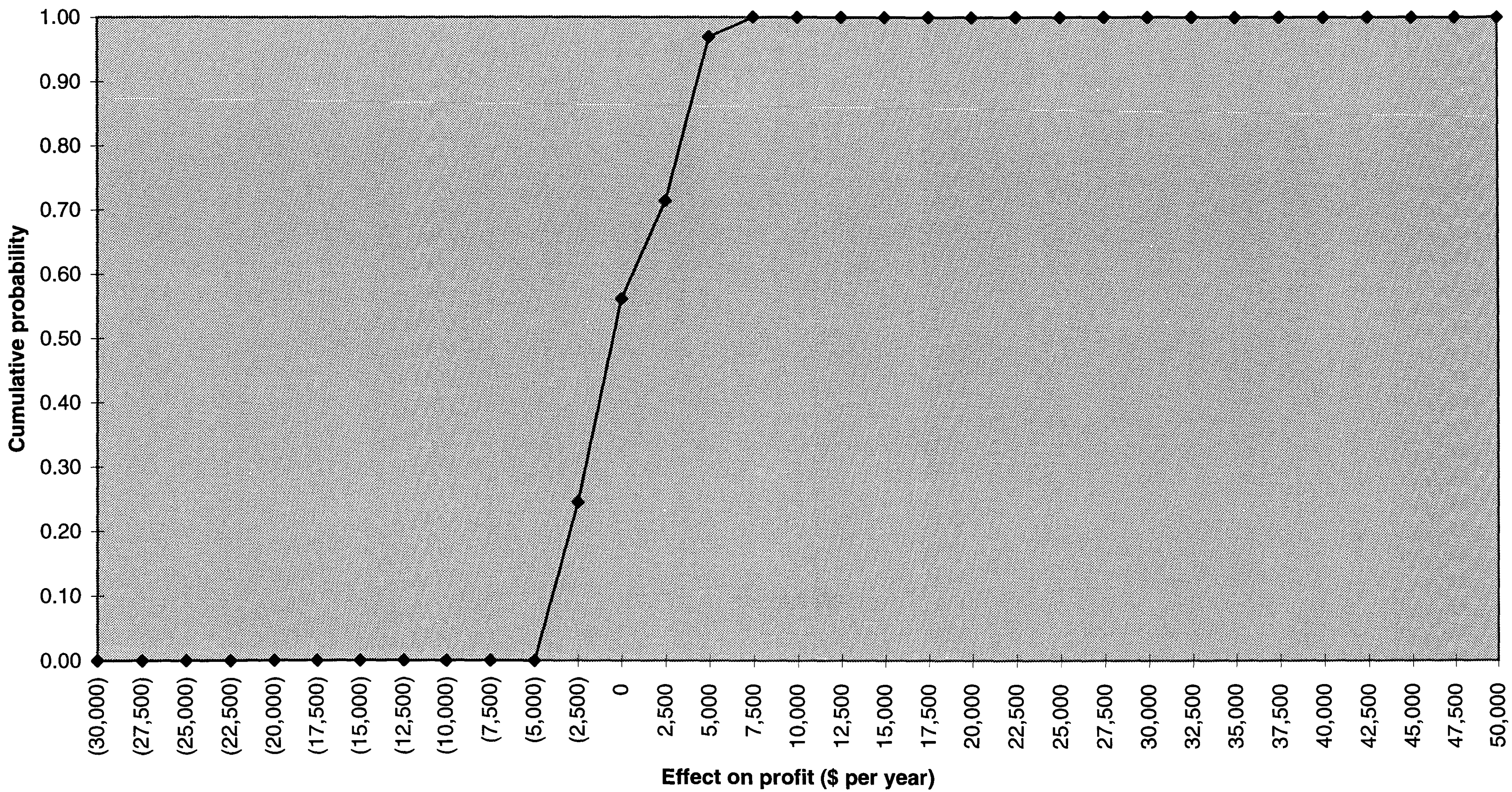

Cumulative Probability of the Effect of Forecasts on Profit
15th May planting opportunity, SN = 70, SW = 50%, Rr = 0
Cumulative probability
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
1.00
(30,000)
(27,500)
(25,000)
(22,500)
(20,000)
(17,500)
(15,000)
(12,500)
(10,000)
(7,500)
(5,000)
(2,500)
0
2,500
5,000
7,500
10,000
12,500
15,000
17,500
20,000
22,500
25,000
27,500
30,000
32,500
35,000
37,500
40,000
42,500
45,000
47,500
50,000
Effect on profit ($ per year)


Cumulative Probability of the Effect of Forecasts on Profit
26th May planting opportunity, SN = 70, SW = 50%, Rr = 0
Cumulative probability
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
1.00
(30,000)
(27,500)
(25,000)
(22,500)
(20,000)
(17,500)
(15,000)
(12,500)
(10,000)
(7,500)
(5,000)
(2,500)
0
2,500
5,000
7,500
10,000
12,500
15,000
17,500
20,000
22,500
25,000
27,500
30,000
32,500
35,000
37,500
40,000
42,500
45,000
47,500
50,000
Effect on profit ($ per year)

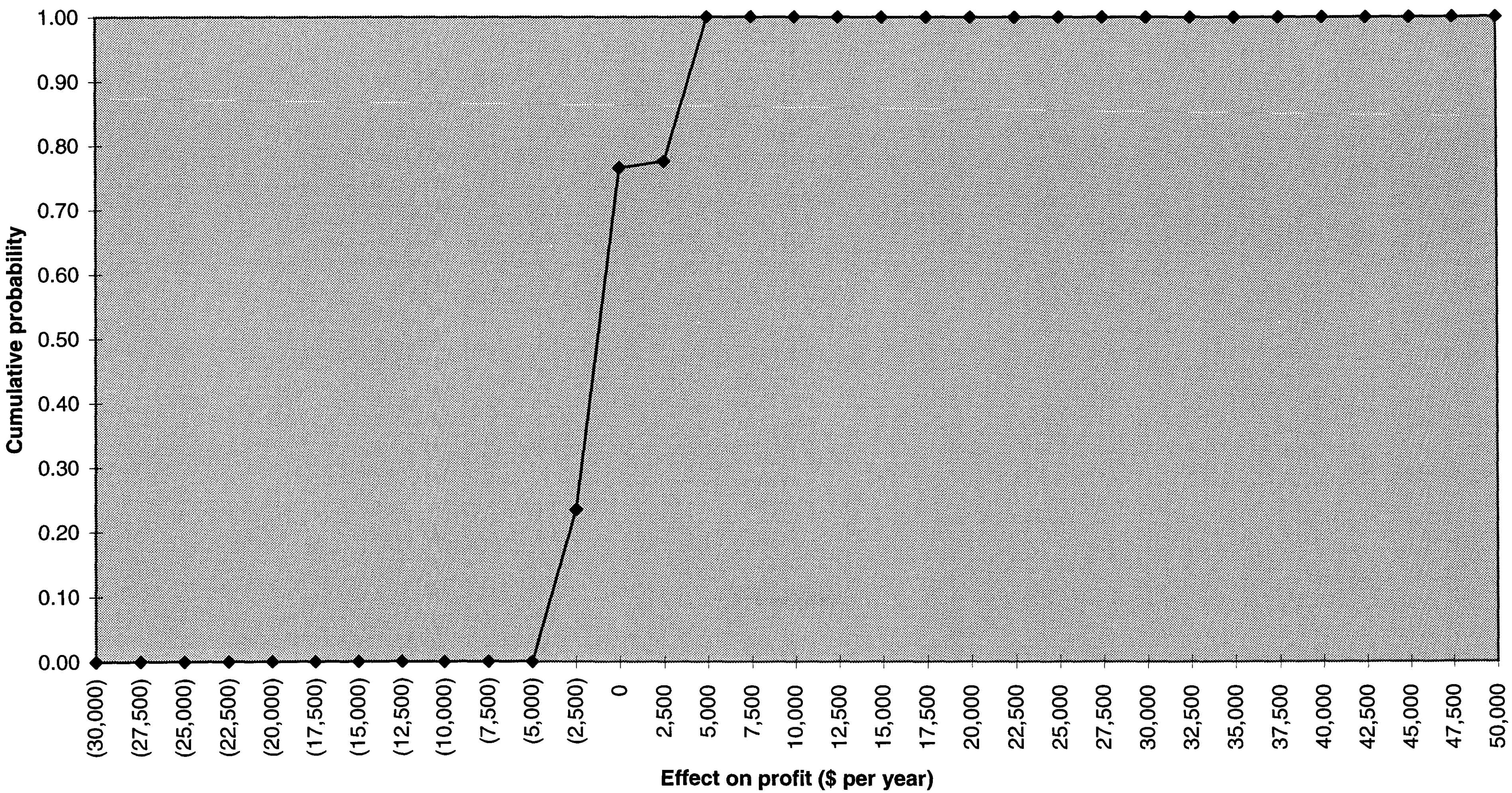


Cumulative Probability of the Effect of Forecasts on Profit
3rd June planting opportunity, SN = 70, SW = 50%, Rr = 0
Cumulative probability
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
(30,000)
(27,500)
(25,000)
(22,500)
(20,000)
(17,500)
(15,000)
(12,500)
(10,000)
(7,500)
(5,000)
(2,500)
0
2,500
5,000
7,500
10,000
12,500
15,000
17,500
20,000
22,500
25,000
27,500
30,000
32,500
35,000
37,500
40,000
42,500
45,000
47,500
50,000
Effect on profit ($ per year)

Cumulative Probability of the Effect of Forecasts on Profit
15th June planting opportunity, SN = 70, SW = 50%, Rr = 0



Cumulative Probability of the Effect of Forecasts on Profit
28th June planting opportunity, SN=70, SW=50%, Rr = 0



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