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WHY A 100-YEAR TIME HORIZON SHOULD BE USED FOR GLOBAL WARMING MITIGATION CALCULATIONS

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1. Ton-Year Accounting

In efforts to combat global warming, decisions have to be made on how carbon accounting will be done for various possible mitigation options. “Ton-year” accounting has been proposed as a way to make units comparable for such options as avoided fossil fuel emissions, avoided deforestation, and silvicultural plantations with different durations. Ton-year accounting can be combined with discounting or other time-preference weighting mechanisms to reflect societal choices on the value of time. Ton-year accounting includes the decay of carbon in the atmosphere in the baseline (no-project) scenario and, depending on the method, also in the project scenario. In order to make the comparison, it is necessary to establish a time horizon within which the areas of the integrals of two curves are compared, one curve being for the baseline scenario and the other for the project scenario. In one method the carbon in the project scenario is followed in the biosphere (Moura-Costa and Collins, nd), while in another (the “Lashof method”) it is followed in the atmosphere (see explanation of different methods in Fearnside et al., nd). The curves are drawn with tons of carbon on the Y-axis and years on the X-axis; the areas under the curves (discounted or not) represent ton-years (Fig. 1). In the example in Figure 1, a 50-year delay reduces the atmospheric impact of a one-ton emission from 46 ton-years to 28 ton-years; the corresponding credit for such a delay would therefore be 46-28=18 ton-years, or 40% of the total. Ton-year accounting can be used for both CO_2 and non-CO_2 greenhouse gases, as well as with discounting over the course of the time horizon (see Fearnside, 1997 for examples of both).

[Figure 1 here]

Ton-year accounting has been resisted by different interest groups for very different reasons. Some of those interested in promoting silvicultural plantations believe that the system gives insufficient financial incentives to project developers because carbon credit accrues too slowly. Others promoting forest preservation through creation of forest reserves think that it gives inadequate weight to the permanent nature of the reserves. On the other hand, Brazilian diplomats resist it because it provides the intellectual underpinnings for giving credit to avoiding deforestation by reducing clearing rates, which is perceived as a potential incentive to foreign interference with Brazil's sovereignty in Amazonia. These "ulterior" concerns, justified or not, can be reflected in a perhaps unconscious desire to find a theoretical argument on the basis of which ton-year accounting can be rejected. This author's perception is that this frenetic search for moral high ground has settled on attacking the choice of a time horizon as immoral because it supposedly writes off the interests of all future generations beyond the end of the horizon.

2. Choice of a Time Horizon

The choice of a time horizon is a policy decision, not a scientific result. In order for policy makers to arrive at decisions on the matter that reflect the interests of society they must think through both the factors on which time horizons are based and the consequences of different choices.

The importance of time will be expressed in two decisions: time preference weighting (for example by discounting) and choice of a time horizon. First of all, it is important to understand that both decisions are unavoidable—there is no option not to make either of them. In the case of time preference, using a time-preference weighting of zero (i.e., a zero discount rate) is just as much a decision as picking any other number. In the case of establishing a time horizon, the horizon cannot be infinite. If it were, everything would be infinite (costs of global warming, mitigation, etc.), and one could not compare the things that need to be compared for decision making. However, the effect of minimizing time preference that would motivate choice of an infinite time horizon could be achieved by picking a finite but far-distant horizon, say 2000 years. However, policy makers must ask themselves if such a choice would reflect the values they want to have governing the behavior of the economic actors who will be responding to the incentives set in place by the carbon accounting system.

Setting a time horizon has an effect similar to the choice of a discount rate. If one sets a short time horizon, say 20 years, even with a discount rate of zero one has the effect of attributing a high value to time. The 20-year integration global warming potentials offered by the IPCC as one of the options in each of its assessment reports provide an example. The inter-relationship between time horizon and discount rate is shown in Figure 2. The joint effect of time horizon and discount rate means that decisions on these two parameters should be taken simultaneously.

[Figure 2 here]

If one sets a long time horizon, say thousands of years, one has the effect of giving almost no value to time if the same zero discount rate is applied, and will encourage behavior that does not distinguish between events now and, for example, several decades in the future. This is obviously inconsistent with the behavior of virtually all professionals involved with the climate issue, who are working very hard to produce the foundations for speedy action on climate change. In other words, we behave as though time had great value. The United Nations Framework Convention on Climate Change states clearly the urgency of identifying and altering any potentially dangerous atmospheric concentrations of greenhouse gases.

If we really thought that events thousands or millions of years in the future should have the same weight as events today, we would be paralyzed in terms of action from day to day in our own time. We would spend our time contemplating our status as tiny specks of matter in a universe with billions and billions of stars, and the few years that we have to live as a mere instant in the great sweep of time between the big bang and the eventual collapse of the universe. Instead, we all use a variety of psychological tricks to give value to time. One of them is focusing on a finite period of time during which we hope to be able to influence events. People set time horizons as a means of focusing their efforts on a period that results in productive action. This should be taken as a virtue, not as a selfish and immoral excuse to write off the rest of history.

Why pick 100 years? Obviously, other choices could be made, but the choice is not entirely “arbitrary” in the sense that the decision maker is free to pick any number from zero to infinity without serious consequences. Several lines of reasoning indicate a figure in the range of 100 years as a wise choice, aside from the fact that the Kyoto Protocol has already specified 100 years as the time horizon applying to global warming potentials for comparing different greenhouse gases.

One hundred years corresponds to approximately the time that decision-makers today have direct contact with the living population. Consider as a hypothetical example that the decision-maker is 50 years old, that the children of each generation are born when the parents are 25 years old, and that all people die at age 75. The decision-maker's great-grandchildren (the last people known directly to the decision maker) will die in year 100. A discontinuity in our contact with the future therefore falls at about 100 years.

The 100-year mark also corresponds to a discontinuity in the relationship between time horizon and its discount-rate equivalent (Fig. 2). In this example, assuming no discounting over the course of the time horizon (i.e., the 0% curve in Fig. 2), the discount-rate equivalent of the time horizon falls from infinity to 1%/year as the time horizon increases from zero to 100 years; after year 100 the decline is much slower, gradually falling from 1% to 0% over the length of the calculation (1000 years in this case). Choices of time horizons shorter than 100 years therefore imply values for time that may be greater than decision makers would like (although, in theory, one could compensate for the time horizon effect by applying a negative discount rate).

One hundred years also represents approximately the maximum time horizon at which one can get away with using a zero discount rate without provoking glaring distortions in current decision-making. The well-known difficulty in arriving at consensus on values for discount rate often results in zero values being selected based on the mistaken assumption that using a zero value avoids having to make a decision. Should this not improbable scenario unfold in the coming rounds of climate negotiations, a 100-year time horizon would at least maintain values within a reasonable ballpark.

The choice of a time horizon will greatly affect the behavior of those who invest in mitigation options. If the horizon is too long, then the return to investors in mitigation projects will be insufficient to motivate them to enter this field at all. On the other hand, if the time horizon were made very short in order to give developers a quicker financial return and boost the profitability of mitigation relative to other kinds of possible investments, the horizon might be so short that the decision-maker's immediate interests in other spheres were sacrificed. A risk exists that developers might lobby successfully for adoption of a very short time horizon, say 25 years.

It is advisable to examine the practical implications of different choices of time horizon before taking a decision, independent of whether one wants to engage in "gaming" of the result, that is, picking a time horizon that, when decisions are made about mitigation, will lead to an outcome that is desired for other reasons. If one chooses a very long time horizon, say 2000 years, and combines it with discounting of carbon, the effect is that temporary sequestration or delayed emissions of carbon on the scale of time normally affected by today's decisions (less than a century) become insignificant. In other words, only "permanent" changes, such as avoided fossil fuel emissions, would be chosen as mitigation options. If one chooses a very short time horizon, say 25 years, the effect is to favor options that give quick returns, such as avoided deforestation and, to a lesser extent, plantations of fast-growing species.

An important policy decision that would affect the consequences of choosing a short time horizon is whether any provisions are established in climate negotiations creating a liability for what happens after the end of the time horizon. Part of the attractiveness of ton-year accounting for mitigation project proponents is that it can provide a rationale for freeing them of such liabilities. This, however, touches on a legitimate concern for global climate: whether the accounting system should include either an adjustment or a liability for emissions occurring after the end of a time horizon. This applies both to standardized time horizons for comparing different options on the basis of ton years (such as the 100-year horizon proposed here) or to the period of a given project.

Ton-year accounting has advantages over methods that use creation of a perpetual liability as a means of justifying credit that is given immediately (i.e., in advance of actually achieving the carbon results). One is that it allows the project proponent to obtain actual carbon credit as the project goes along, rather than waiting until the end of the project to obtain any financial returns beyond what may be negotiated in a futures market. Another advantage is that it provides a means of avoiding sovereignty concerns in countries hosting the projects. Such countries are likely not to want to promise to keep specific tracts of land in forest, perpetual-rotation plantations or any other specific land use in perpetuity, but ton-year accounting offers a means of allowing projects to be credited as they go along and to be terminated at any time that the host country may wish, while minimizing both damage to the climate system and the need for liabilities that may be difficult to collect in practice.

3. Financial Mechanisms and Carbon Credit

As pointed out above, some of the concern about establishing a time horizon may be, in fact, a disguised manifestation of concern with the ton-year accounting as potentially making mitigation projects inviable by not offering investors enough return in the early years of their projects to keep them interested in devoting their money to mitigation. However, it should be emphasized that financial mechanisms are, or can be, separate from carbon accounting. If it is decided that funds must be provided to project developers in advance of their actually producing the carbon benefits, this can be done by loans and contracts through financial institutions, without giving credit for carbon benefits that are still only promised. Caution should be used in subsidizing such systems, however, as they can potentially distort the reasons for which the carbon-accounting system was established.

One cannot logically expect to receive the financial benefits immediately from mitigation measures if the actual benefits for climate only accrue over many years. If one invests money by putting it in a savings account for ten years, one only receives interest at the end of each interest period; the bank does not offer to pay all of the interest for the ten-year period on day one, in exchange for a promise that you will leave the principal in the account for ten years. If avoided fossil fuel emissions are to be compared fairly with carbon sequestration from forestry projects, it is important that the timing of the carbon crediting be on the basis of the time that each option produces real benefits for the atmosphere. It would be unfair to give full immediate credit for the avoided fossil fuel emission because of the certainty that its atmospheric benefit will not be reversed, whereas the sequestration project must wait to receive its credit in parcels after the terrestrial carbon stocks have been created, held and verified. This potential inequality could be addressed by crediting the avoided fossil fuel emission on the same basis: as small parcels extended over a 100-year time frame.

While the mechanism of granting carbon credit in small parcels over many years would solve the problem of unequal treatment for the two classes of mitigation measures (energy sector vs. biotic "sinks"), it would also have the undesirable effect of making all mitigation less financially attractive. One option for dealing with this is to simply grant the carbon credit for all options at the outset. This would negate some of the advantages of ton-year accounting for biotic sinks (reducing the need for long-term liabilities and avoiding potential objections to mitigation projects on the grounds that they infringe sovereignty by requiring countries to promise to maintain specific land uses for long periods or even permanently). Another option would be to grant carbon credit over time, but to create a futures market that would pay financial rewards at the outset. Avoided fossil fuel emissions would receive a (deserved) advantage in such a market because of the certainty that the promised carbon credit will, in fact, accrue.

4. Beyond the Time Horizon

It bears mention that one can devise ways to deal with the interests of generations "after 100 years" by assigning them a fixed amount of effort that is represented as a discrete block, as if it were at a single point in time—not as the long tail of a negative exponential distribution. In the example in Figure 3, 10% of the total weight is given to the period beyond the 100-year time horizon. This 10% is represented by the bubble at the right-hand side of the graph. At the end of the 100-years, the 10% weight that remains could then be allocated over the following century following the same system, including the 10% transfer to the following century. However, from the point of view of accounting being done now, only the first century plus the "bubble" would be considered (*i.e.*, Figure 3).

[Figure 3 here]

5. Conclusion

In conclusion, some decision on time horizon is inevitable. It is an illusion to imagine that one can avoid choosing a time horizon and give consideration to an infinite period, even if discounting decreases the weight applied to the long-term future. Applying either very short or very long time horizons can create perversities for decision making. A variety of arguments converge on a value of around 100 years as a wise choice, in addition to the perhaps coincidental choice of a 100-year time horizon that has already been made by the Kyoto Protocol for global warming potentials of the different gases.

6. References

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FIGURE LEGENDS

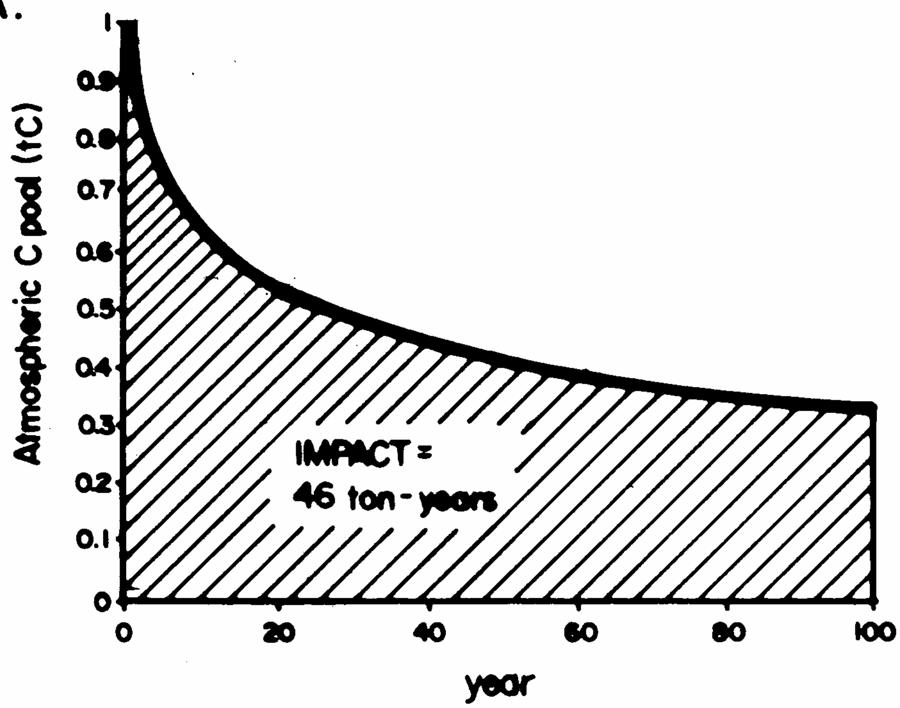
Figure 1: An example of ton-year accounting using the "Lashof method," a 100-year time horizon and no discounting over the time horizon (see Fearnside et al., nd for detailed explanation of methodology). In this example a baseline (no-project) scenario (Panel A) represents carbon in the atmosphere if one ton of carbon is emitted in year 0, while in the project scenario (Panel B), one ton of carbon is sequestered, for example in trees, and is emitted in year 50. The ton-year benefit will be the sum over the 100-year time horizon of the differences between the atmospheric loads of carbon at each year, weighted by the time preference at each respective year (always equal to

one in this example without discounting, making the difference between the areas under the curves a direct measure of the carbon benefit).

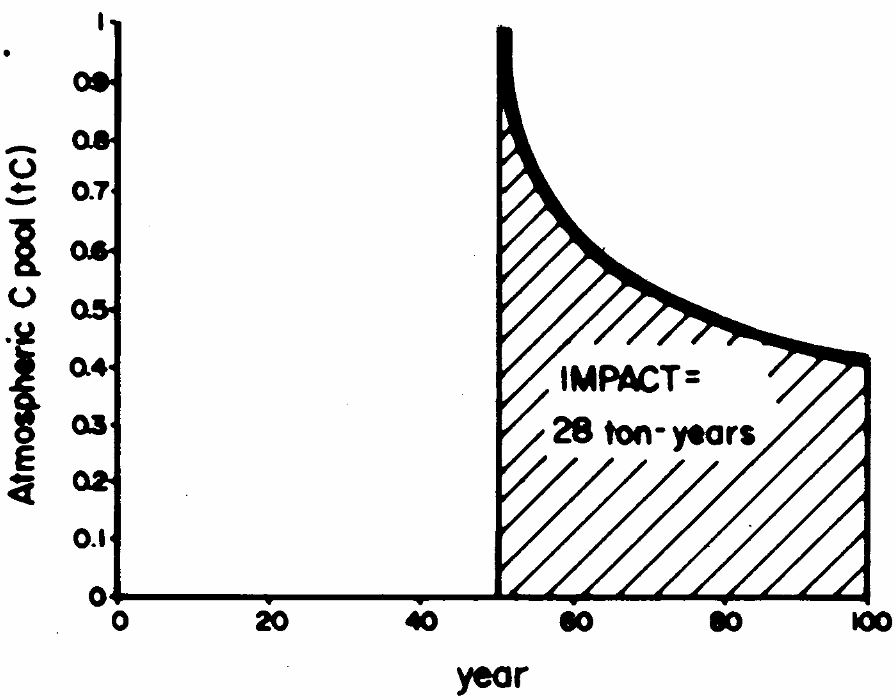
Figure 2: Relationship between time horizon, the discount rate applied over the time horizon and the discount-rate equivalent of the combined result over a 1000-year period. The effect of a 100-year time horizon with no discounting is approximately equal to a 1% annual discount rate over a 1000-year time horizon (i.e., the integrals of the two will be equal). If annual discount rates of 1% or 2% are applied to time horizons of different lengths, the discount-rate equivalent of the combined result will be a higher annual percentage than if no discounting (i.e., 0% annual discount). In the case of a 100-year time horizon, the discount-rate equivalent of 1% with no discounting rises to 1.6% and 2.3%, respectively, if annual discount rates of 1% and 2% are applied over the course of the time horizon.

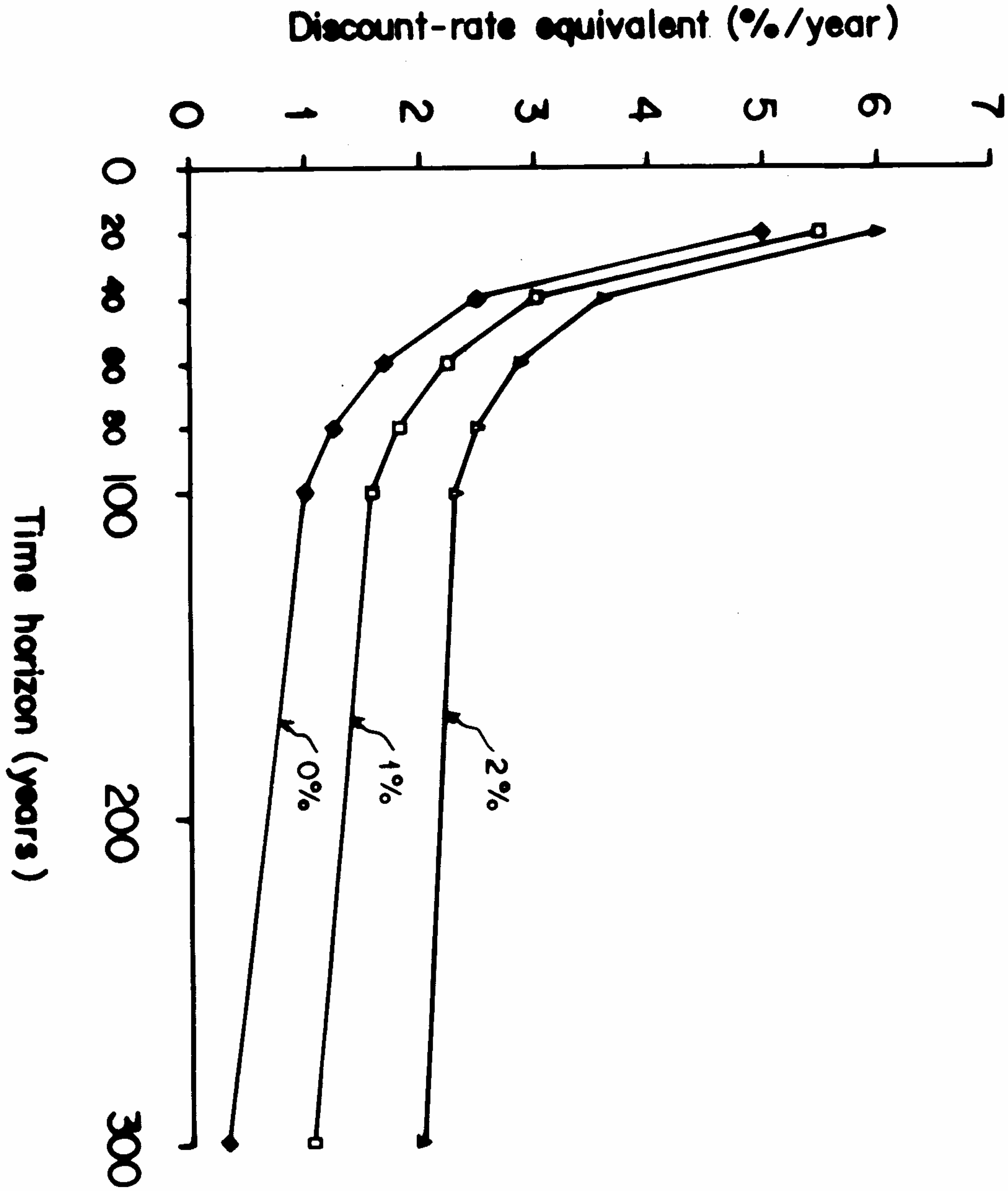
Figure 3: A possible mechanism to transfer a given proportion of decision-making weight to the period beyond the end of the time horizon. In this example, 10% of the total weight, represented by the area in the "bubble" at the right-hand end of the curve, is passed to the subsequent century.

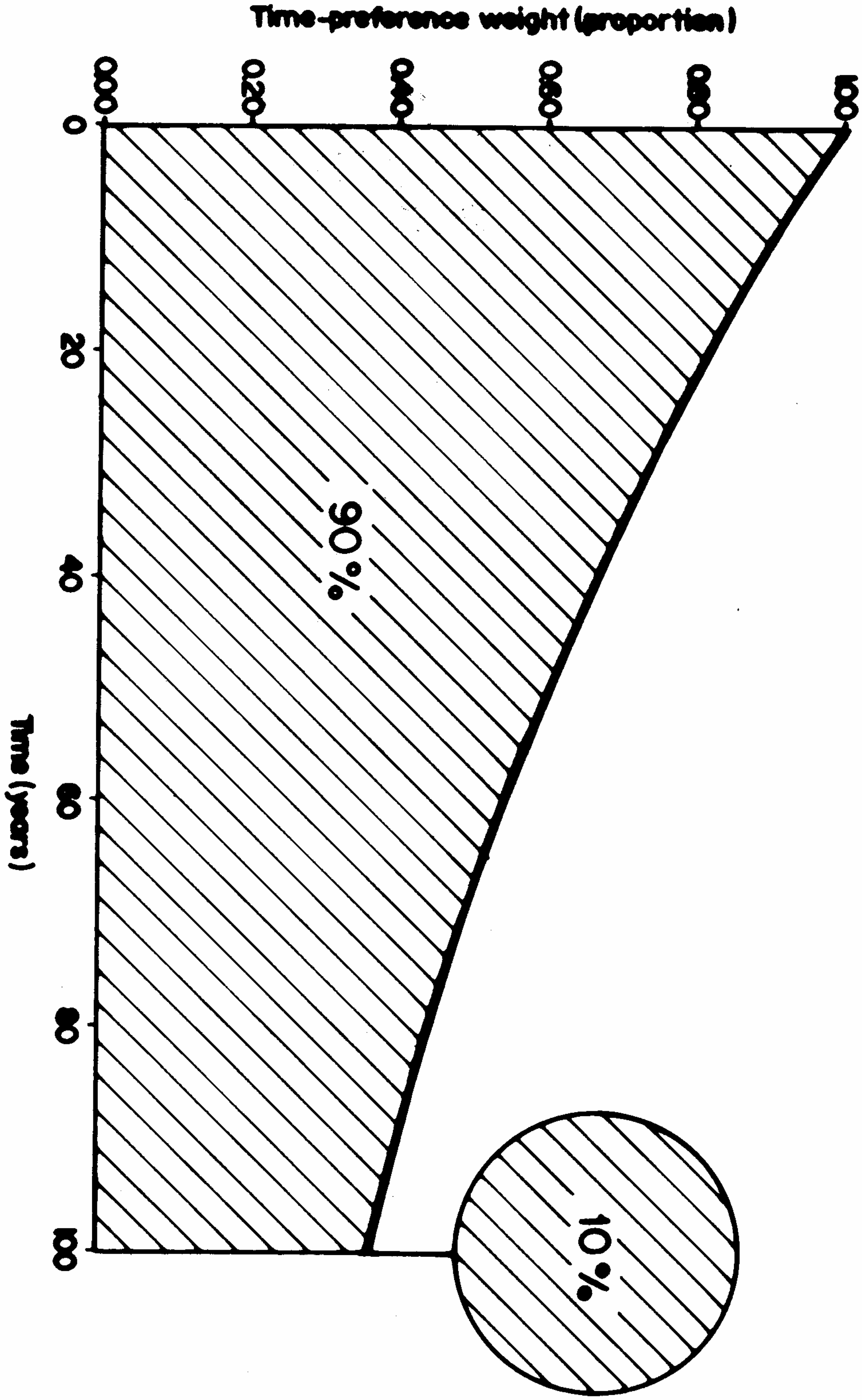
A.


Atmospheric C pool (tC)
IMPACT =
46 ton-years
year
0
20
40
60
80
100
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1

B.


Atmospheric C pool (tC)
IMPACT =
28 ton-years
year
0
20
40
60
80
100
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1


Discount-rate equivalent (%/year)
0
1
2
3
4
5
6
7
Time horizon (years)
0
20
40
60
80
100
200
300
0%
1%
2%



Time-preference weight (proportion)
0.00
0.20
0.40
0.60
0.80
1.00
0
20
40
60
80
100
Time (years)
90%
10%