Sustainable Resource Use By Peoples' Participation

A Game Theoretic Justification

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Common examples of renewable common property resources are forests and irrigation water. Forests grow at a certain rate and need limited appropriation for sustainable use. Water resources are exhausted every year and are renewed again by nature. But appropriation of natural precipitation often requires infrastructural facilities. Sustainable resource use in this case means regular maintainance of the appropriation structures . This involves cost, sometimes nominal , sometimes substantial, which make room for sharing and participation of beneficiaries. Indeed, participation cannot occur unless there is a cost component. For appropriation of forest resources costs enter in the form of necessary vigilance and make room for beneficiary participation. However, there is a more meaningful way for understanding costs in case of forest resources. Judging by the utility curves or the labour required for appropriation one can always determine a maximum rate at which a user can extract the forest resources. But he may be required not to function at the maximum capacity if he is interested in the sustainance of the forest. The restraint shown by the user in such cases is the participation for sustainibility. The portion that could have been , but was not, extracted can be conceived as the cost. In fact , there is no difficulty in cosidering the costs of regeneration of the renewable resources under this component . Thus, resource use can be expressed by two components : gross benefits (B) and costs of

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ppropriation (M^*). A general formulation for sustainable resource use is where the two components are so well-managed nat the net benefits $B^* - M^*$ recurr over a long time , conceptually, for ever.

It is easy to conceptualise sustainability in terms of aggregates. But each agent receives only a fraction of the enefits. How can they ensure the sustainability of the aggregates? Let us first formulate the situations the ndividual beneficiaries face. Let us consider that there are $i = 1, 2, \ldots\ldots n$ beneficiaries and the gross benefits ach receive are b_i and costs each incur are m_i . For some j's the b_j and/or m_j may be zero. Thus non- eneficiaries (and non-cost sharers) can be excluded without complicating the formulation. Sustainable resource use is ne where the i-th benefeciary incurs a cost m_i and receives a benefit b_i such that :

$$\sum_i b_i^* = B^* \quad ; \quad \sum_i m_i^* = M^*$$

n other words, in case of forest resource exploitation the aggregated appropriation must not exceed the sustainable ate; in case of irrigation water total appropriation costs for sustainable use must be met. Of course , the aggregate ppropriated benefits may be less than B^* or the incurred costs more that M^* without endangering sustainability. But such Pareto-inefficient cases may be omitted.

The utility received by the i-th individual is given by $u_i(b_i - m_i)$. He/she may have many feasible options to ncrease the current utility by disregarding the sustainablity question . Those options which meet the sustainability onditions for the aggregate can be called <u>co-operation</u> for sustainable resource use. Those other options which, f realised would affect sustainibility may be called <u>defection</u>. Understandably, whether a choice is co-operative or not is determined only after aggregation with choices made by others. There can be many such combinations , or imputations that satisfy the sustainability conditions in B and M. There is no way to claim , from within the Game Theory - one or the other imputation (b_i, m_i) as the <u>just.</u> Current ethical practices may favour one kind of imputation as equitable. But sustainability conditions may be met by many other imputations. It follows that sustainable management does not necessitate equitable distribution of benefits, a claim that is often made to explain the basis of popular participation in this area.

Let us assume, for simplicity, that there are only two beneficiaries , i = 1 and 2 and only two choices available to each of them C_i = co-operation for sustainable use and D_i = defection from that. The pay-offs for the two strategies are given by :

$$u_i^* = u_i(b_i^* - m_i^*) \quad \text{for } C_i \text{ strategy}$$

$$\text{and} \quad u_i = u_i(b_i - m_i) \quad \text{for } D_i \text{ strategy.}$$

Let us also denote $u_i = a u_i^*$; $a > 1$

The term a has a simple meaning . In the case of forest use, assuming that the cost component is nil , $a = \dfrac{u_i(b_i)}{u_i(b_i^*)}$, i.e. the ratio of the utilities under full and part capacity utilisation . In other ords, a gives an idea of how much of one's capacity of forest resource exploitation was sacrificed for the sake of ustainability. In case of irrigation it shows the increase in current utility that could have been obtained by not articipating in the cost sharing for appropriation, that is by free-riding. It is also noteworthy that by adopting C_1 trategies the players expect the resource to last for ever. But with D_1 strategies the players, even independently, xpect the resource to get exhausted after some years, say, after n_1 years. By definition here, n_1 is the redictable aspect of the future. It depends on the (i) regeneration rate of the renewable resource, (ii) the hare of the i'th user on the resource and (iii) the maximum extraction capacity of the user. There are also ncertain aspects in the life expectancy of a resource, e.g. because of a natural calamity. This has been absorbed in he discount rate for the future, introduced later.

The current payoffs of the strategy combinations can then be expressed as :

1 \ 2	C_2	D_2
C_1	u_1^*, u_2^*	x_1, u_2
D_1	u_1, x_2	x_1^*, x_2^*

where x_i's represent the unexpected losses suffered by opponent's defection strategies. One need not enter into the deductions of x_i values. Since $u_i > u_i^* > x_i$, depending on the relative magnitudes of the x values the game is either a Prisoners' Dilemma or a Chicken, neither of which has (C_1, C_2) as equilibrium.

The situation we are actually concerned with is represented by a supergame with several iterations of the above pay-off matrix. Its equilibrium need not be the same for one-shot game. Since each player has a strategy that ends the game after finite number of iterations, in n_1 period, the backward induction results cannot be straightway excluded. However, in an alternative manner the game may be hypothesised as infinitely repeated but the pay-offs after a certain stage, become zero. Folk theorem may then be applied to ascertain that there are strategy paths by which co-operatively feasible outcomes of the game can be achieved. The question is, the outcome may be feasible but will it be desirable for the players ? The players may find that by overexploitation up to a finite period their utility is maximised. Although it is convenient for mathematical exercises to postulate an infinite horizon for utility maximisation of players, in real life human beings do not plan for eternity. They have only limited horizon in sight, either ones own lifetime or the lifetime of a few generations of progenies. Alternatively, one may have the duration of occupancy right over the resource as the time horizon. One way to formulate this problem is to suggest a strategy path where, at every point of time, the players try to maximise their utilities over their own time perspectives. Let us redefine as that the current period decision making occurs in terms of the discounted aggregate utilities. Let these new pay-offs be denoted by - R, T, S, P so that the current period game is :

	C_2	D_2
C_1	R_1, R_2	S_1, T_2
D_2	T_1, S_2	P_1, P_2

As introduced earlier, in cases of (D_1, C_2) and (C_1, D_2) strategies the resources are expected to last only n_1 and n_2 years respectively. If both defect, its life expectancy is even less, say, n_3 years.

Let the discount rates for future utilities be denoted by w_1 and w_2, $0 < w_1 < 1$. The discount rate actually means future consciousness. While companies may be guided by something like the bank interest rates human beings rarely have any definite way to judge how much to value the future benefits. Some may have the philosophy of living day to day, some others may desire that not only they themselves in their old ages but also their children should enjoy the resources just as much. Some may strongly believe that there will be a doomsday. Some others may be optimistic of a scientific breakthrough that would obviate the necessities of that particular resource. Indeed, how exactly do people discount the future is not known. Here we are making a distinction between the material aspects that determine n_1 and the philosophical aspect that makes people weigh the living conditions in the future.

The discounted pay-off matrices may now be written as :

$$R_1 = u_1^* + w_1 u_1^* + w_1^2 u_1^* + \dots\dots\dots\dots = \frac{u_1^*}{1 - w_1}$$

The others are finite series aggregates and equate to :

$$T_i = \frac{1 - w_i^{n_i}}{1 - w_i} u_i$$

$$S_j = \frac{1 - w_j^{n_i}}{1 - w_j} u_j^*$$

$$P_i = \frac{1 - w_i^{n_3}}{1 - w_i} u_i$$

Only in such cases where $R_i > T_i$ for both i's the strategy pair (C_1, C_2) is an equilibrium. That the strategies are *self-enforcing* in equilibrium implies that the users voluntarily participate in sustainable use of the resource. Of course the (D_1, D_2) too can be another equilibrium. The co-operative strategies constitute the unique equilibrium only when $P_i < S_i$ too is satisfied. But that is merely of mathematical interest. It may also be noted that in such cases where $R_1 > T_1$ but $R_2 < T_2$ the only possible equilibrium is (D_1, D_2). A necessary condition for sustainable use is therefore , both the players find long-term co-operative outcomes as the better between their two strategy options.

By comparing the values above one finds $R_i > T_i$ if $w_i^{n_i} > 1 - \frac{1}{a_i}$. Thus, however large may be a there is always some w value where the inequality holds and co-operation for sustainable use of resources by sacrificing part of one's current utility or by incurring the required cost may occur voluntarily. The following chart shows the critical values of n, the life expectancy of the resource as estimated by a user, under different (a , w) combinations. If the n value is below the critical level the inequality $R > T$ holds and particiaption for sustainable use is an equilibrium strategy.

CRITICAL VALUES OF n

\w a\	0.500	0.900	0.990	0.999
1.10	3.5	22.7	238.6	2396.7
1.50	1.6	10.4	109.3	1098.1
2.00	1.0	6.6	68.7	692.8
5.00	0.32	2.1	22.2	223.0
10.00	0.15	1.00	10.5	105.3
100.00	0.01	0.09	1.00	10.0

As is evident, if the future is discounted at a rate less than unity there is always a finite value of n above which co-operative strategy will not be adopted . Thus, the general strategy path of the renewable resource users may be described as : when the resource in question is available in plenty and the users are not worried that it may be exhausted , participation for sustainable use is unlikely. However, gradual depletion or sudden calamities may bring down its life expectancy below the critical limit whereafter a switch in one's strategy may occur. But co-operative equilibrium is not yet definite since the critical life expectacy of the resource to the other user may be at still lower level . At this stage, if at all there is an equilibrium, it is in excess exploitation by both. In concreteness, this may be a phase where the two users try to impress on each other their respective viewpoints. If depletion continues at this stage too, the life expectancies of the resource to each user reduces further and may eventually cross the critical level for the second one. Thereafter , co-operative behaviour for sustainable use may be an equilibrium strategy combination.

From the chart it is also evident that those who have very little underutilised capacity , and a reasonably high rate of discounting, are the ones likely to show participatory tendencies. Those who have to sacrifice a lot of extraction capacity (or incur considerable cost as in the case of irrigation) for sustainable use (i.e. high a) do not, in general , show participatory tendencies until they anticipate imminent danger of resource depletion, or, they have a very very high discount rate nearing unity. Who are these people ? The Companies which are generally guided by the market rates of interest for valuation of future returns are unlikely candidates for participation in sustainable use of resources. They may do so only when the house is on fire, that is , the danger of depletion looms in the immediate future. But by then it may be too late to take corrective measures. Worse among them are those who have to sacrifice a lot of capacities for participation in sustainable use. Such Companies are not likely to rise to the occasion until the last moment. At the other extreme are the very small users who receive only a minute part of the total benefit because of a very small share in the resource. They would not expect susbstantial reduction in the critical life expectancy of the forest even if they increase their extraction capacities severalfolds. In other words, they are so very small sharers that they do not even envisage that their participation in sustainable resource use may have any significance. They too are not likely to be participants for sustainable use. By excluding both of these groups one gets a clearer understanding of the users who are the most likely participants for sustainable use. Certainly, they must have high discount rate for the future returns - without this basic committment there is no chance of success with anyone. However, within those having high discount rates one can also indicate a preferred section. They must be significant share-holders of the benefits so as to observe the positive effects of their participation. If the renewable resource is divisible to some extent, parts can be assigned to small groups of people to create this effect. They should not have excessive extraction capecity, which generally comes through intensive commercial operations. It seems that there is some substance when the environmentalists argues in favour of renewable resource management by small groups of local people.