

SMITHSONIAN INSTITUTION FOREIGN CURRENCY PROGRAM RESEARCH FIELD TRIP PROPOSAL:

Institution submitting proposal

University of Michigan

Title of proposal:

PROPOSAL FOR A STUDY OF THE POTENTIAL IMPACT OF INSTITUTING A DESERT REGENERATION PROGRAM ON THE CARRYING CAPACITY OF WESTERN RAJASTHAN, INDIA, FOR A HUMAN POPULATION

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Signature of Principal  
American Investigator

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ABSTRACT

The proposed study is directed at the regeneration of the largely man-made desert in Rajasthan, Northwest India. The objectives of the study are two: 1) to examine in detail the ramifications of instituting a program of desert regeneration on production of livestock, and 2) to perform a synthesis of information needed for estimating the carrying capacity of the area under present and various assumed future conditions. The model proposed is particularly strong in being a stochastic one which makes allowance for the probability distributions associated with both production and regeneration.

In addition to the relations surrounding the provision for regeneration, the model in its most complete form takes into account resource allocation, changes in the exploitative technology, consumption levels, resource distribution, and government aid levels, plus the variance tolerances about key terms in the carrying capacity equation. In a simplified form for use in making a preliminary estimate of the carrying capacity some of these terms are set by making assumptions based on current patterns.

There are two pressing needs related to carrying capacity estimates: 1) a first rough approximation based on available data for the use of government planners in making policy decisions needed now, and 2) experiments and data collection programs for the use of future policy makers, and revision of plans to be initiated now. The main thrust of the proposed research is directed at the first of these needs, but in making this preliminary estimate an eye will be kept for possible future work related to the second as well.

**I.) OBJECTIVES OF THE STUDY:**

The proposed study is directed at the regeneration of the largely man-made desert in Rajasthan, Northwest India. The objectives of the study are two: 1) to examine in detail the ramifications of instituting a program of regeneration of the desert on production of livestock, and 2) to make the beginnings of a synthesis of the information necessary to estimate the carrying capacity of the area for a human population, both under present and under various assumed future conditions. The model proposed is particularly strong in being a stochastic one which makes allowance for the probability distributions associated with both production and regeneration.

The need for a program to regenerate the Rajasthan Desert has been recognized by the Government of India, which maintains the Central Arid Zone Research Institute (C.A.Z.R.I.) in Jodhpur, Rajasthan to conduct research related to this problem. The Government of India also has recognized the need to control the country's population, and has set a target of cutting the 1971 growth rate of 2.5% per annum in half by 1978-79 (Saxena, 1971, p.11). In order for Government planners to set goals such as this, they must have some idea of what the carrying capacity of the country will be in the year for which the goal is set. Such a carrying capacity estimate must, of course, take into account the various other kinds of goals the Government has set for itself, such as eliminating poverty and providing for the regeneration of the Rajasthan Desert. An estimate of the impact of a desert regeneration program on the production of the arid zone in Rajasthan is therefore an important step in the task of making a carrying capacity estimate of the region of the type needed by Government planners.

It should be noted that Government planners may wish to make a distinction between a carrying capacity figure which corresponds to the standard of living which they consider the minimum acceptable, and the target they set for the population size. They may wish to maximize the standard of living by reducing

the population as much as possible below the carrying capacity. In any case, they will need to know the carrying capacity figure corresponding to their minimal goals for the standard of living in order to insure that their population policies are consistent with achieving a standard at least that high.

An assessment of the impact of a regeneration program requires a crossing of many of the traditional professional and academic boundaries. Reid Bryson, a climatologist from the University of Wisconsin who recently made a noteworthy contribution on the potential for reversing the man-caused trend toward drying of the climate in Rajasthan, had this to say:

...I would like to see working on this problem (control of the desert in Rajasthan) some experts on range management and others on the social structure and on land tenure. I think what we need at the international level is true interdisciplinary work, rather than to leave the science to the scientists and the social stuff to the social people: put them together and find a solution. Perhaps what we really need to do is to restructure some of our UN units so that people of diverse backgrounds can apply their expertise to common problems that require interdisciplinary and practical solution. (Bryson, 1972)

Such a synthesis of information from many fields is one of my objectives.

I believe that there is a pressing need for a rough first approximation of the carrying capacity to be made immediately. Policy decisions are needed now, and therefore the first approximation of the carrying capacity must be based on whatever data is available, no matter how incomplete or statistically nonsignificant. Policy decisions which are being made now, either actively or by default, are implicitly making assumptions about what the carrying capacity of the region is. Such decisions could benefit from the synthesis of whatever data exists now, rather than foregoing an immediate approximation in favor of a more complete study to be completed at a later time. A second need, which is separate and independent of the first, is to set up experiments and data collection programs which will give more reliable estimates of the carrying capacity for the use of future policymakers, and revision of plans to be initiated now.

My intention on this initial research field trip is to direct my efforts towards the first of these needs. This will involve educating myself through synthesis of the results of past studies, observations of experiments already in progress at the C.A.Z.R., and consultation with the scientists at the C.A.Z.R.I. and other institutions who are working on problems related to this. This does not mean that my commitment to solving this problem ends with the computation of one rough first approximation of the carrying capacity. Once this initial goal is achieved, I would hope to be of help to the researchers there in their efforts to collect more data in ways that will yield more refined and reliable estimates of the carrying capacity.

## 11.) THE MODEL

### A. GENERAL OUTLINE OF CONSIDERATIONS IN MAKING A CARRYING CAPACITY CALCULATION:

A schematic representation of some of the links leading to a carrying capacity determination is given in Figure 1. This systems-like representation is best read from the bottom up starting with the total resource base (eg. land). The links in the reasoning fall roughly into two parts: the first being the series of links between the land and the amount of product produced, and the second being the series of links leading from the amount of product produced to the number of people that can be supported. The restrictions on the production system are of two types: restrictions on the average amount of product produced and restrictions on the variability to be allowed in the amount of product produced. Brief descriptions of some of the links shown in Figure 1 are given as a part of Table 1.

The complex maze of connections can be greatly simplified as a first approximation by arbitrarily making a long list of assumptions about the components and links in the system. Table 1 includes a listing of some of the simplifying assumptions that could be made, and where appropriate, where data needed for validating the assumed values could be found. This is given only for the boxed

components in Figure 1, not for the connections between components. A "bare bones" diagram of carrying capacity relationships with the most simplifying possible assumptions is given as Figure 2.

Some of the different kinds of assumptions appearing in Figure 1, and others that might eventually be added to the "bare bones" model shown in Figure 2, could be categorized as follows:

1.) **STATIC ASSUMPTIONS:** This is the simplest formulation which is often used in studies of relatively simple systems such as slash-and-burn agriculture. I have used this simplifying set of assumptions myself in making a carrying capacity estimate of a shifting agriculture system in Costa Rica (Fearnside, 1973). The definition of carrying capacity of William Allen (1949) used by Street (1969) is: "the maximum number of people that a given land area will maintain in perpetuity under a given system of usage without land degradation setting in." Often "a given system of usage" is interpreted to imply (by H. C. Conklin (1957, p. 146), among others): a.) unvarying technology and crop patterns, b.) qualitatively constant per capita food consumption and c.) quantitatively constant per capita food consumption.

2.) **DYNAMIC ASSUMPTIONS:** This adds the assumptions of technology and consumption change.

3.) **RESOURCE DISTRIBUTION ASSUMPTIONS:** These could include minimum standard of living assumptions whereby everyone would be brought above the official government "poverty line." Additionally "optimal distribution" constraints could be added to give a carrying capacity figure for whatever resource distribution the planner wished.

4.) **ENVIRONMENTAL CHANGE ASSUMPTIONS:** The stipulation in the traditional definition of no land degradation can be modified to allow either a fixed rate of degradation deemed acceptable by the planner, or, as the Government's commitment to work towards regenerating the Rajasthan Desert would indicate, a modification could be made to allow for a set rate of regeneration.

These assumptions can, of course, be applied in various combinations. It is the fourth of these assumptions, the assumption of regeneration rate, on which I will concentrate. This will be used first with the static assumptions regarding consumption and technology, and later, data being available, some form of dynamic assumption could be added, followed eventually by the resource distribution assumption.

It has been pointed out with reference to the static assumptions that carrying capacity estimates based on these should be far from valueless to the population planner (Ehrlich, 1968, among others). Since development of newer technologies is something that can be projected into the future only with great uncertainty, it would be unwise to endorse a population policy that chances the welfare of the population on the assumption that a technology not yet in operation will be operating as planned at a specific time in the future. At such time as the new technology is actually in operation, the carrying capacity estimate can then be revised upward and the population easily increased to take up the slack if so desired. This argument, of course, holds only for the comparison of static models with dynamic ones which assume that projected changes will raise the carrying capacity!

It might also be pointed out that as carrying capacity estimates go the case of Rajasthan has at least one saving grace in terms of simplicity. Since marked environmental degradation is already taking place, the present population is clearly over the figure for the carrying capacity assuming present goals for the standard of living and the "bare bones" assumptions regarding resource distribution. This makes the problem of arriving at a figure for the carrying capacity much simpler than in the reverse case where the population is somewhere below the carrying capacity at the time of the study. The Pandora's box of problems related to picking the limiting factor is much simpler, as the array of difficulties in assessing the potential for space as a limiting factor can be bypassed. The complex cultural factors of "individual distance" (Hall, 1959), the distribution

of crowding stress in space (Galle, 1972) and time (Ehrlich & Ehrlich, 1971) can for the most part be avoided. Only potential problems of settling nomadic peoples as a part of the regeneration program could result in these kinds of space-related stresses becoming limiting (Turnbull, 1972; Calhoun, 1972).

Unless other information to the contrary becomes available, it will be assumed for the purposes of this study that the limiting factor will be one of the more tangible problems that are causing the present degradation of the land: deforestation for fuel and the food production system through grazing. Potential production of these is fairly tightly circumscribed by the amount of water.

B.) IMPACT OF INCORPORATING A TIME TABLE FOR REGENERATION ON THE CARRYING CAPACITY MODEL:

1.) IMPACT ON STOCKING RATE AND PROPORTION OF LAND ALLOTTED TO PRODUCT:

With the general objective in mind of collecting information related to the determination of a carrying capacity, effort will be focused on certain particular links in the chain of relations lying between the land and the number of persons that can be supported. The first such focal point will be the implications of providing for various set rates of environmental change, in other words the effect of adding a time table for regeneration of the desert on the number of people that can be supported.

The consequences of adding a regeneration time table can be seen in either Figure 1 or Figure 2. The most immediate consequences are two: a certain amount of land will have to be withdrawn from production each year for reseeding and fallowing, this reduces the proportion of the land of this quality being used to produce the product, which reduces the total amount of the product produced and hence the supportable population. The second immediate effect is setting a limit on the allowable rate of exploitation of the resource, or stocking rate. The stocking rate limit must be set such that the regeneration rate is not less than the minimum limit set, and also such that the variance about this mean rate

of regeneration does not exceed a limit on the maximum variance in the regeneration timetable which has also been set by the planner. A more time-delayed effect of adding the provision for regeneration will be an increase in the amount of land present in the better land quality categories and a decrease in the amount of land present in the poorer categories. Since calculations of the amount of product produced must be made separately for each land quality category and then summed over all categories to give the total amount of product produced, the upgrading of the land quality will eventually lead to greater total production and hence a larger figure for the number of people supportable.

It should be possible to determine the maximum stocking rate allowable given the limits set on the mean and variance in the regeneration timetable, plus one additional constraint in the form of a limit set by the planner on the variance of production. A fourth constraint could also be added whereby the mean production would be bounded above by the environmental degradation associated with this which is not explained by the stocking rate. This fourth constraint will not be considered here, however.

One would expect the mean rate of regeneration to decrease as the stocking rate increases for obvious reasons. One would also expect the variance in the regeneration rate to increase with increasing stocking rate as more minor perturbations in the weather would, for example, result in grazing goat populations eating through the narrower margin of fodder production to cause a set-back in the regeneration schedule. The variance in the amount of product produced can also be expected to increase with increased stocking rate. As with the variance in the regeneration rate, an increased stocking rate could more easily result in a goat population, for example, running out of fodder during a dry spell leading to a dip in the production per goat and possibly also a drop

in the population size of the goats. The increased crowding from increased stocking rate could also increase the probability of loss due to insects, disease, etc. The chance for permanent damage to the environment also increases as this margin of production decreases.

These three determinants on the maximum allowable rate of exploitation or stocking rate are shown graphically in Figure 3. As is shown in the figure, different outcomes could result from different slopes in the relationships between these three factors and the stocking rate. In the first case the variance of production is limiting, in the second it is the mean regeneration rate, and in the third case it is the variance in the regeneration rate which is limiting. Different outcomes could also be produced by changing the limits, shown by horizontal dashed lines in the figure, which are set on the basis of value judgments made by the planner. The way in which these limits are set once the planner has defined his goals will be explained later.

The assumption that the relationships graphed in Figure 3 are linear is one which is made only as a first approximation for ease in interpreting the model. The effects of the myriad of possible synergisms could be incorporated later as a further refinement. In reading the graphs in Figure 3 one should move from left to right (in the direction of increased stocking rate); the first of the three variables being graphed against stocking rate (the solid lines) to cross its respective limit (dashed line) then becomes the limiting factor, and the corresponding value on the abscissa becomes the maximum allowable stocking rate. The vertical scales of the three variables are, of course, all different, but this does not affect the outcome as each variable and its respective limit are plotted using the same scale.

A list of priorities must be set up for determining the relations involved in calculating a maximum allowable stocking rate. I would order them as follows:

- 1.) a regression of the variance of production on the stocking rate.
- 2.) a regression of the mean regeneration rate on the stocking rate.
- 3.) a regression of the variance in the regeneration rate on the stocking rate.

2.) FACTORS AFFECTING THE PROBABILITY OF PRODUCTION FAILURE AND ITS FEEDBACK ON STOCKING RATE:

The limit on the total probability of production failure (a measure of the variance in production) is set by the planner. To this amount of permissible variability in total production can be added an additional amount of variability made possible by the amount fixed by the planner of permissible peak and cumulative amounts of government aid to production during famines. The resulting total amount of allowable variability in the local production machinery must then be apportioned among the various factors contributing to production failures. These include such factors as the variance in prices of goods needed for production which are bought from outside and the predictability of rainfall. To the extent that these two factors are not under the control of the planner, the feedback from the limitation on variance of production must be directed through the other element shown in Figure 1: the probability of loss due to insects, disease, etc.

The way in which this amount of allowable variance is apportioned among the three contributors to the probability of loss due to insects over which the planner has control: the stocking rate, the technology (such as new breeds of goats, etc.), and the proportion of the available land budgeted for production of this product. As each of these variables increases one would expect both an increase in the production (the "value" in economics terminology) and an increase in the probability of a loss due to an outbreak of insects, disease, etc. (the "costs" in economics terminology). These two can be scaled together in some fashion, and the combination of stocking rate, technology, and proportion of land can be found which maximizes the difference between the value and the costs

subject to the constraint that the total probability of failure not exceed the limitation fixed by the planner (Koopman, 1951; Karlin, 1959).

Under the "bare bones" model with the simplifications shown in Figure 2 (page 34) this becomes greatly simplified as only the stocking rate is considered. The particular values for the probability of insect or disease loss that are associated with those values for technology and the proportion of available land allotted which were fixed as a part of the simplifying procedure are subtracted from the limit on the total probability of loss due to insects and disease. This gives a new limit, which corresponds to the "limit on the variance of production" shown graphically in Figure 3 (page 35). The various subtraction steps used in deriving this limit in the "bare bones" model are shown diagrammatically in Figure 4 (Page 36).

### 3.) FACTORS AFFECTING THE MEAN AND VARIANCE OF REGENERATION RATE AND ITS FEEDBACK ON THE STOCKING RATE:

The generation of any one of these regression equations will, of course, require the measurement of a multitude of variables. Stocking rate is not the only variable affecting the resultant mean and variance in the regeneration rate or the variance in production. Other variables, the effects of which might have to be corrected for in the model to unmask the relation of the stocking rate on the mean and variance of the regeneration, might include:

- 1.) rainfall, both the total and the amount falling during certain critical times of the year.
- 2.) the treatment given the land, such as contour furrowing or reseeded. Perhaps this could be measured in terms of cost, corrected for the expected benefit (Jodha, 1968), or scaled in some other fashion.
- 3.) The grazing schedule is also important (Naveh, 1968). The time of year that grazing occurs can make a great difference in the resulting damage to the

plants for a given amount of forage eaten. Penning of livestock and feeding them on stored fodder during the most critical times of year can substantially raise the carrying capacity for livestock. Rotational grazing is another alteration on the grazing schedule that can raise the carrying capacity (Fearnside, 1973b), and it has been recommended for certain places in Western Rajasthan (Gupta & Saxena, 1966). Some sort of scaling of the grazing schedule with reference to the resultant damage to the plant is therefore needed.

4.) man hours put into tending and managing the herd might be an easily measureable variable that would reflect on subsequent regeneration.

5.) The effects of plant diseases and insect pests, both in terms of the amount of plant matter eaten or destroyed and the timing or importance to the plant would affect regeneration.

In addition to these, much more data would be available if appropriate corrections could be made for such different and otherwise uncomparable conditions as:

1.) Different species of grazing animals might be corrected for based on the amount of fodder consumed, the method apparently used by Jodha (1968). The best possible correction for different animal species would also correct for the relative damage to the plant depending on the part and amount of each different species of plant eaten, etc.

2.) Different range quality classes might be corrected for based on the predicted yield of edible fodder. This could include ranges on different soil types, etc.

3.) Different range plant species communities might be comparable if correction is made on the basis of the amount of fodder production, but other corrections might also be necessary.

Once available data has been collected and standardized as much as possible for each of these other variables to isolate the effect attributable to stocking

rate, then a limit can be set on the maximum permissible decrease in the mean and increase in the variance of the regeneration rate due to increased stocking rate. This is done in a manner similar to that done with the probability of a production failure. The factors contributing to the mean and variance in the regeneration rate are shown diagrammatically in Figures 5 and 6 respectively, together with a representation of the subtraction procedure used to derive the limits on these factors used in Figure 3. Here again there are more than one contributing factor over which man has some control: the manhours put into tending, the cost of the treatment (or a correction of this for predicted benefit), the grazing schedule, and all the other characteristics of the utilization pattern lumped under the heading "exploitation technology" in Figures 1 and 2. In addition to these factors which are directly under the control of man, the contribution from insects and disease not explained by the stocking rate is also partially under man's control through the proportion of available land allotted to any one product, large monocultures being more susceptible to insect-caused disasters than diversified land use patterns (Janzen, 1970).

An optimization procedure can again be used here to maximize gains and minimize losses. The costs in terms of added variance in the regeneration timetable or decreased mean regeneration rate must be quantified on the same scale as both the other costs associated with each of these factors and the benefits to be had from them in the way of added production. Additionally, two of these factors: the time spend in tending and the cost of the treatment probably serve to reduce the variance in the regeneration rate and shorten the timetable. These therefore serve to raise the limit on the variance in regeneration rate due to the stocking rate, and likewise to permit a higher stocking rate before crossing the bound on mean regeneration rate as well. In the "bare bones" model the contributions from all of these variables is considered fixed at the present level with the exception of the stocking rate.

### C.) OTHER VARIABLES:

As can be seen from the diagram in Figure 1, there are many other links in the model which I have not described here. These links will not be considered in this first "bare bones" approximation, and will be left for further refinements of the carrying capacity estimate. Although the variables related to each of these will not be described here, their inclusion in the diagram in Figure 1 will help focus attention on these for future perfections of the estimate. My commitment to work on carrying capacity problems for Rajasthan does not end with the "bare bones" model, and I hope to incorporate some of these additional variables after achievement of the first priority goal of a rough first approximation of the carrying capacity as outlined in this proposal.

### III.) BENEFITS TO THE SMITHSONIAN FROM SPONSORING THIS RESEARCH:

#### 1.) PROBLEM OF MAJOR IMPORTANCE:

The problem of estimating the carrying capacity so that Indian policy-makers can make decisions that will allow the achievement of their various goals, including the regeneration of the Rajasthan Desert, is one of major importance. The effect of research related to this problem therefore need not end with the publication of the results, but has the potential of application which will be of immediate benefit to large numbers of people.

#### 2.) PROBLEM REQUIRES IMMEDIATE ATTENTION:

The desert in Rajasthan continues to spread, thus lowering the area's carrying capacity. The population growth in the area also continues to widen the gap between the present population and one consistent with the ability of the land to support a human population. Both of these considerations mean that it will be far more costly to regenerate the desert at a later time than it would be now. Research in this vital area should therefore be funded now, rather than being postponed to a later time.

### 3.) GENUINE INTEREST OF INDIAN GOVERNMENT IN PROBLEM:

The genuine interest of the Government of India is evinced by the founding and continued support of the Central Arid Zone Research Institute in Jodhpur. The Five Year Plans clearly indicate the intent of the Government to bring the population of the country in line with the carrying capacity. (G.P.I., 1951; 1964; 1969). The Fourth Five Year Plan Outline refers to limiting the birth rate as the "kingpin of the Plan" (Raina, 1969, quoted in Saxena, 1971, p. 11). The history of governmental awareness of the importance of carrying capacity has been a continuing theme since the 1946 report of the Health Survey and Development Committee, which states: "the question of the need of cautious adjustment between the population and the resources that are available cannot be ignored and should receive serious consideration." (Dhore, 1946, p. 477, quoted in Saxena, 1971, p. 8).

### 4.) CONTINUING RESEARCH PROGRAM OF C.A.Z.R.I.:

The results of my study would be a part of a larger continuing effort on the part of the C.A.Z.R.I. and the Indian Government. The existence of this program means that forthcoming results would have a greater chance of being pursued further by researchers there, and would also have a greater chance of being taken into account by the Indian Government officials who must formulate and implement policy.

### 5.) MUCH EXCELLENT WORK DONE BY C.A.Z.R.I.:

The large number of excellent studies done by the researchers at the Central Arid Zone Research Institute on specific components in the carrying capacity model will make the pay-off from applying the model far greater than had this pioneering background work not been done.

6.) MINIMAL DUPLICATION OF OTHER RESEARCH:

Although much information on the specific components of the carrying capacity model has already been collected, the problems related to fitting this information into a general carrying capacity model constitute an area which has great need of additional research effort. This has two important implications: 1.) the ample room for more researchers in this particular piece of the research niche-space means that my work would in no way compete with or duplicate the efforts of other researchers on the scene, on the contrary, my work is designed to complement the efforts of the other scientists; and 2.) the Smithsonian could expect to reap a high return from support put into this new area of research as the law of diminishing returns has not yet begun to assert itself. In short, the state of research is such that the Smithsonian is in a position to have the best of both worlds, enough background work having been done to add to the value of the results, yet not so much that further research expenditures result in duplication of effort and reduced return on the research investment.

7.) POSSIBLE BENEFIT TO U.S. & INTERNATIONAL AID-GIVING AGENCIES:

Programs initiated by the Indian Government to regenerate the Rajasthan Desert may well be a good focal point for aid from other countries. Equipment may be needed for such a program for computerizing, monitoring, etc., as well as advice on solving specific technical problems as they arise. The administrators in such international agencies, as well as the Indian administrator who decides what kinds of aid are needed, would surely find the results of research such as this useful.

8.) METHODS DEVELOPED WILL BE APPLICABLE TO OTHER AREAS OF THE WORLD:

Problems similar to those in Rajasthan exist in many areas of the world, including the United States of America. Carrying capacity estimates are needed

for these areas, and all experience gained in making this kind of estimate will ease the way to solving the problems in these areas as well.

#### IV.) PLAN OF WORK

##### A.) METHODOLOGY:

The first order of business will be doing some concentrated library research at the Central Arid Zone Research Institute in Jodhpur. Many of the C.A.Z.R.I. publications are not available at the University of Michigan. I will pay particular attention to collating all data presently available on exclosure reseeding and stocking rate experiments. This information needed for prediction of the time table for regeneration program, including information about the variance to be expected in regeneration rates under different possible programs, will surely be scattered enough to require some concerted searching. At the same time I will try to interview a wide variety of workers in an effort to educate myself to the insights they have gained in their own specialties and to get guidance in finding all of the information that exists on the critical variables in the carrying capacity model. The most important sources of information will probably be the researchers of the C.A.Z.R.I. In addition to these workers I would approach as many of the Government officials as possible including Rajasthan Animal Husbandry personnel at all levels, District Collectors, Block Development Officers, etc. The files in these offices often contain a great deal of information if one has the patience to ferret it out -- a task at which I became quite proficient in my two years of service as an American Peace Corps Volunteer in the Rajasthan Animal Husbandry Department (Fisheries Division). I would also try to approach both State and Central Government servants concerned with planning. I would also speak with academicians in a wide range of fields at such institutions as the University of Jodhpur and the University

of Rajasthan in Jaipur. I would try to synthesize the information gathered according to the framework of my carrying capacity model, starting with the links involving the amount of environmental change.

**B.) SCHEDULE OF WORK:**

July 1, 1973 (or as early as May 1 if this proposal can be approved by then)	Arrive, New Delhi
July 2-7	Travel to Jodhpur via Jaipur
July 7-20	C.A.Z.R.I. for use of library facilities, interviews with researchers, U. of Jodhpur, Government officials and other sources of information in Jodhpur
July 20 - Aug. 20	Travel in Western Rajasthan; interview District and Block-level workers, observe C.A.Z.R.I. study areas and interview field researchers.
Aug. 20 - Aug. 27	C.A.Z.R.I., Jodhpur continue interviews and reading (may wish to continue field observations or proceed to Jaipur first, however)
Aug. 28 - Sept. 3	Jaipur for interviews with state-level officials, use of State Government records, and interviews at the University of Rajasthan.
Sept. 4-9	Delhi for interviews with Central Government officials, use of Central Government records, possible information from international aid agencies, etc.
Sept. 9	Depart for U.S.A.

Note: 1) this proposal represents only a preliminary study and may be followed with additional proposals for more detailed studies.

Note: 2) this schedule is very approximate, and of course would have to remain flexible to allow extended stays where information is most available and abbreviated stays where it is not.

V.) THE STATE OF KNOWLEDGE:

A.) THE MAGNITUDE OF THE PROBLEM:

The desert in Rajasthan covers an area of about 214,039 sq. km., or 60% of the total area of the State (Jodha, 1968). Some of the outstanding features of the desert are listed in Table 2. The desert produces an enormous plume of dust with densities at the peak over Rajasthan of 600-800 micrograms/m<sup>3</sup> up to heights of 3,000 to 9,000 m, which makes the air more than 2-4 times as heavily loaded with particulates as the air over Chicago (Bryson, 1972). The plume of dust extends all the way from Arabia to Cambodia (Bryson, 1972). Climatologists have only recently come to the conclusion that this dustiness is the reason for the area's aridity (Bryson & Baerris, 1967; Wendland & Bryson, 1970; Bryson, 1972). The dust in the atmosphere explains earlier observations of a discrepancy between the rate of diabatic cooling calculated without provision for dust and the rate of cooling necessary to maintain the sinking of the air. It is the sinking of the air which results in the stable, desertic conditions. Measurements by Bryson et al. (1964) and Mani et al. (1965) confirm the relation of dustiness to the unusual cooling rate which accounted for the sinking air.

There is a wealth of evidence that the area which is now desert in Rajasthan once support a high culture and had a lush forest characteristic of areas with much higher rainfall. This includes evidence from sculptures in the Mathura region circa 500 B.C. to 640 A.D., references in the writings of Herodotus of 400-500 B.C. vintage, and references in the Ramayana and Mahabharata which were composed between 200 and 500 B.C. (Randhawa, 1945). The vegetation was lush at the time of Alexander the Great (Puri, 1960 V.I p. 261). There is also pollen evidence for a much wetter climate at the time of the Indus Civilization about 1000 B.C. (Singh, 1967, 1969, and 1970). The climate began to show evidence of dryness about 1000 A.D., but the drying trend has been more pronounced in recent years (Bryson, 1972).

The high particulate matter content of the atmosphere has been justly ascribed to the intense utilization of the land by man: ground cover cannot remain established under intense grazing pressure from sheep and goats. I have observed personally innumerable examples of this during my own two-year stay in Rajasthan. More and more land is being pressed into cultivation, much of it marginal in the extreme. The switch from herding to cultivation is a common consequence of population pressures (Doserup, 1965), and when done on marginal land often results in deserts (Sears, 1935).

The area of the arid zone in Rajasthan used solely for grazing decreased from 13.09 million hectares in 1951 to 11.04 million hectares in 1961, a decrease of 15.6% (Jodha, 1966). At the same time the population of grazing animals increased by 53.2% from 9.4 million in 1951 to 14.4 million in 1961 (Jodha, 1968). The estimated average annual production of forage on these grasslands is less than 300 kgs/hect, while grazing stress is estimated at about 8 cattle equivalents/hect. (based on ratios of 1:6 for the effect of cattle: sheep or goats and 1:1 for cattle: other kinds of livestock, and on the cattle census reported in Anonymous (1964) (Kaul & Chakravarty, 1968). This is of a different order of magnitude than the "grazing capacity" for adult cows on a year-long basis of 12.2, 8.0, 4.9, and 3.6 hectares/cow for 'poor,' 'fair,' 'good,' and 'excellent' range condition classes respectively in an area with 319 mm of annual rainfall (Ahuja, 1961, quoted in Ahuja, Bhimaya & Samraj, 1968). Other reported grazing capacities include 2.5 sheep/hect on poor rangeland at Pali (Dabadghao, 1959b), from 6.93 to 7.60 sheep/hectare on sown pasture at Pali, depending on the species of grass (Kaul & Chakravarty, 1968), 6 hect/cow on rocky rangeland at Kailana (Jodhpur) (Kaul & Chakravarty, 1968), and 2.47 sheep/hect. on natural pasture at Pali when grazed only 324 days/yr (Das et al., 1963).

The desert is apparently advancing into surrounding arable land, but the reported rates of advance vary among among authors. Talbot (1957), followed by

Bryson & Baerris (1967) and Ehrlich & Ehrlich (1970, p. 166) reports one-half mile per year. Ehrlich gives a rate of enlargement in area of 6,000 sq. miles per year, while Talbot gives a value of 700 sq. miles/year. Puri (1960, p. 259), referring to Hora (1952), states that "the Planning Commission's estimate of 50 sq. miles per year may not hold much scientific ground," and points to the lack of data.

B.) WHAT IS BEING DONE:

Whatever the rate of advance of the desert, it is agreed by many that the trend can be reversed through proper management and reduced population pressure. A research program related to reclamation and control of the desert in Rajasthan was begun by the C.A.Z.R.I. in 1958. The C.A.Z.R.I. now maintains 52 research areas varying in area from 60 to 80 hectares in ten districts of the desert region (Bhimaya et al., 1966). Exclosure experiments, such as the C.A.Z.R.I. program involving 22 range management areas fenced for 6-7 years, show regeneration when grazing animals are excluded (Kaul & Chakravarty, 1968). There are several scattered exclosure experiments in other parts of India confirming this, such as Burns and Chakradav, 1921).

The prospects for pasture development are bright, and such developments can repay the money invested through added production. Jodha's (1968) study found a cost:benefit ratio of from 1:3.47 for reseeding alone to 1:5 for treatment with contour furrowing. A similar study in West Pakistan (French, 1968) found cost:benefit to be 1:3 with reseeding.

A number of workers have made lists of recommendations for improvements, such as those of Raheja (1964b) and Gupta and Saxena (1966).

A good deal of background information has been accumulated, which will be helpful in designing range improvement studies. These have been listed in the bibliography, where a plus sign (+) after the reference indicates its availability at the University of Michigan, and minus sign (-) indicates its absence.

Background information on the origins of the Rajasthan desert include:

Krishnan (1952a & b); De Terra & Hutchinson (1936-37); Sajani (1964); Sen (1962); Ahmen (1969); Chhiffer (1949); and Wadia (1937, 1954).

Literature on the climate in Western Rajasthan includes Banerji (1952); Bhatia (1957); Gov't. of India (1960); Krishnan (1963, 1968); Krishnan & Rakhecha (1965); Krishnan & Shankarnarayan (1964); Krishnan & Tyanvi (1969); Labrousse (1965); Meher-Homji (1965, 1967, 1968); Pramanik et al. (1952); Rao (1958); Sawyer (1947); Subrahmanyam (1958, 1964); Subrahmanyam & Murty (1968); and Govindaswamy (1953).

Literature on groundwater resources of the area includes: Gupta & Abichandani (1968); Pandey et al. (1964); Saksena et al. (1966); Shankarnarayana et al. (1965); Sharma et al. (1953); Taylor et al. (1955); Auden (1950 & 1952); Chatterji (1963, 1965); Chatterji & Rupta (1969); Chatterji & Mondal (1964); Chatterji et al. (1965); Chandhuri et al. (1966); and Dhruvanarayana (1965).

General information on the geography of the area is reported in Sen (1964); Pithawalla (1952); and Singh (1952).

Plant distribution work includes: Bajpai & Verma (1964); Bakshi (1952); Bhandari (1961-1962, 1964, 1967); Bhimaya & Ahuja (1968); Biswas & Rao (1953); Blatter & Hallberg (1920); Bhandari (1963); Croizat (1968); Jain & Kotwal (1961); Joshi (1957, 1958a); Joshi & Sharma (1964); Kanodia & Rao (1965); King (1879); Legris & Meher-Homji (1968); Mathur (1960); Meher-Homji (1962); Mulay & Ratnam (1950); Nair (1956, 1957, 1961); Nair & Joshi (1955); Nair & Kanodia (1959); Nair et al. (1961); Nair & Malhotra (1961); Nair & Thomas (1962); Prakash & Nanda (1961); Puri et al. (1964); Ramachandran (1950); Rao Rolla & Kanodia (1962-63); Ratnam (1951); Sankhala (1951); Sarup (1951, 1957, 1958a,b,c); Shankarnarayan & Satyanarayan (1963); and Sharma (1962).

Plant ecology literature includes: Bharucha (1952); Boyko (1968); Chaudhuri (1957); Dabadgeo (1958, 1960a,b); Gupta & Abachandani (1968); Joshi (1956, 1958);

Joshi & Bansal (1968); Joshi & Vargese (1967); Joshi et al. (1967); Nanda (1967); Puri (1952, 1960b); Raheja (1965); Ratnam & Joshi (1952); Sabnis (1919-1921); Sarup & Vyas (1957, 1958); Satyanarayan (1957, 1958, 1963); Shankarnarayan et al. (1965); Sharma (1963); Sarup (1952); Vyas (1955, 1963); and Vyas & Gupta (1962, 1965).

Some of the literature related specifically to plant production includes: Bhimaya (1967a); Kumar (1971); and Kumar & Joshi (1972).

Information on small mammal pests includes: Prakash (1959, 1962a, 1967); Prakash & Kumbharni (1962); and Prakash et al. (1965).

Insect pest and plant disease literature for the area includes: Alam (1952); Cotes (1891); Joshi (1967); Roonwri & Bose (1964); Srivastava & Pande (1966); and Srivastava & Pandey (1967).

An important body of literature on the classification of land quality includes: Abachandani & Ghose (1964); Bhimaya & Ahuja (1967a, 1969); Bhimaya et al. (1965); Gupta & Saxena (1966); Nanda (1969); Prakash & Ahuja (1964); and Raheja (1966).

Land use information is also essential, and can be found in such sources as Anonymous (1960); Bharadwaj (1961); Bhimaya & Kaul (1968); Gov't. of Rajasthan (1961); Kaul & Mishra (1961); and Sen and Abraham (1966).

Grazing studies are vital to carrying capacity estimations, and include: Ahuja (1962, 1963); Ahuja et al. (1958); Banerji (1948); Chakravarty & Das (1964); Chakravarty et al. (1970); Dabadghao (1959b); Dabadghao & Marwaha (1970); Das et al. (1965); Das et al. (1963); and Kumar & Joshi (1972).

Livestock management and production studies include: Ahuja (1964, 1965, 1966a, 1969); Ahuja et al. (1968); Ahuja et al. (1965); Ahuja et al. (1964); Bhimaya (1967b); Gov't. of Rajasthan (1956); Narayan (1960, 1962, 1964); Patel (1961); and Sapre (1965).

Pasture development studies include: Ahuja (1961); Bhimaya & Ahuja (1967b); Bhimaya et al. (1966); Chakravarty (1968b,c); Dabadghao, Marwaha & Das (1961); Kaul & Chakravarty (1968); Misra & Das (1963); Raheja (1962b, 1964b, 1966b); Ramamoorthy (1964); and Dabadghao (1961b).

Studies on reseeding technology include Chakravarty (1968b); Dabadghao (1959a); Chakravarty et al. (1966); Chakravarty & Verma (1968a); Chakravarty & Bhati (1969); French (1968); Dabadghao et al. (1965); Jodha (1968); Kaul & Chakravarty (1968); Ahuja & Bhimaya (1966); Verma & Chakravarty (1969).

Germination studies on grass seeds include: Ahuja & Bhimaya (1967); Chakravarty (1965); Chakravarty & Verma (1968a); Chatterji & Mukherjee (1969); Lahiri & Karbanda (1963); and Sharma (1965).

Studies in root structure and ecology, an important factor in choosing plants for erosion control, include Bhaskaran & Chakravarty (1965); Bhimaya & Kaul (1965); Chakravarty & Kacker (1966); Dabadghao et al. (1963); and Kaul (1965b).

Other studies related to dune stabilization and erosion control include: Bhimaya & Kaul (1960); Bhimaya et al. (1961); Mishra & Ram Prasad (1966); Misra (1963); Prakash & Pathak (1957); Quadri (1960); Rao (1951); and Sing and Sankhla (1960).

Afforestation and farm forestry studies include: Bhimaya & Kaul (1960); Bhimaya et al. (1964, 1965); Bhimaya et al. (1960); Kaul & Ganguli (1964); Khan (1960); Lamba (1960); Pathak (1956); Raheja (1963); Kaul (1965a,c); Kaul & Chand (1966); and Kaul & Ganguli (1963).

Forage analysis and production studies include: Ahuja (1966b,c); Dabadghao (1961a); Das et al. (1964); Ganguli et al. (1964); Gupta & Saxena (1966); Mondal & Gupta (1966); and Sen and Ray (1964).

Research method studies include such efforts as Jain (1967) and Jain & Bohra (1966) on plot size and Raheja (1964a, 1967) on air photo use in surveys. Work has also been undertaken on various technological solutions to desert problems, such as Lahiri's (1966) work on antitranspirants.

A number of review papers and general commentaries have also been compiled on research and development work. These include Raheja (1962a,c); Raheja & Sen (1964); and C.A.Z.R.I. (1966).

Resource surveys include Satyanarayana (1963); Shankarnarayan et al. (1965); Shankarnarayan & Satyanarayana (1963); Symposium of Natural Resources of Rajasthan (1969); and Vestappan et al. (1969).

Socio-economic survey work includes: Anonymous (1957); Bharara & Bose (1964); Bharar & Sen (1970); Bose (1963, 1963); Bose & Bharara (1965); Bose & Malhotra (1963, 1964); Bose et al. (1963, 1964); Bose et al. (1966); Carstairs (1952); Jodha (1966, 1967); Malhotra (1964); Malhotra et al. (1965); Malhotra et al. (1966a,b, 1967); Malhotra & Bose (1963); Nat. Council Applied Econ. Res. (1962); and Sachchidananda (1964).

Soil literature includes: Abichandani (1964, 1965); Bharucha (1960); Ghose (1965); Gupta et al. (1969); Gupta (1952); Kolarkar and Abichandani (1967); Kolokar & Singh (1970); Krishna (1966); Krishnan et al. (1966); Krishna & Gupta (1952); Misra & Bhatt (1960); Mondal (1967); Mutakar & Raychaudhury (1959); Quershi & Yadav (1964); Raychaudhury (1964); Roy et al. (1969); Sarin (1952); Satyanarayana (1958); Saxena & Basu (1964); Satha & Metha (1963, 1965); and Tamhane et al. (1960).

There also exists a fair amount of literature on the mechanisms of social change in villages, Sen (1969), for example, on mass communication in a desert village. The most important literature on social change are probably those related to population pressure, such as Coale & Hoover (1958) and Boserup (1965) to name two excellent general ones for India as a whole. Another important area is that relating the entire region to the rest of India, such as Hora (1952) on the value of the desert region to the national economy.

VI.) BIOGRAPHY OF PRINCIPAL INVESTIGATOR:

A.) BIRTH: May 25, 1947 Berkeley, California

B.) PHYSICAL: Height: 6 ft. 4 in. (2 meters)

Weight: 170 lbs. (77.5 kgs.)

Health: Excellent

Physical disabilities: None

C.) EDUCATION:

## 1.) Public schools in California &amp; Massachusetts (1952-1965):

Honors: First Place, (Physics), Wellesley Sr. High School Science Fair.

First Place, (Physics), Greater Boston Regional Science Fair.

Wellesley Sr. High School Physics Prize

## 2.) COLORADO COLLEGE (1965-1969):

Ford Independent Study Program Scholar (1965-1969)

B.A. (Biology), 1969

Honors: Phi Beta Kappa  
Magna Cum Laude

## 3.) UNIVERSITY OF MICHIGAN (Jan. 1972 - present):

Degree program: leading to Ph.D. in Zoology

Field of Concentration: Ecology

Teaching fellow positions: see "employment history"

## 4.) ORGANIZATION FOR TROPICAL STUDIES (July - Aug. 1972):

This is an N.S.F.-funded program run by 27 U.S. and Latin American universities. Research projects and field problems are carried out in varied Costa Rican habitats, including the Guanacaste Province. My major effort under the program involved determining carrying capacities for human populations (Fernside, 1973a).

D.) EMPLOYMENT HISTORY:

1.) SUMMER EMPLOYMENT:

- A.) camp counselor: Pine Island camp, Belgrade Lakes, Maine. Summers of 1965 and 1966.
- B.) Ranger Naturalist: National Park Service, Glacier National Park, West Glacier, Montana. Summer 1968.

2.) TEACHING FELLOW POSITIONS:

Half-time positions leading discussion sections and/or laboratory sections for University of Michigan Zoology Department courses:

- a.) Introductory Biology for Natural Science Majors (Bot-Zoo 106). Under Drs. Gellarius, Shappirio, Helling & Martin. Winter term 1972.
- b.) General Ecology (Bot-Zoo 351). Under Drs. F. C. Evans & W. S. Benninghoff. Fall 1972.
- c.) Habitats & Organisms (Zoo 454). Under Dr. D. H. Janzen, Winter, 1973.

E.) PEACE CORPS - RAJASTHAN FISHERIES (1969 - 1971):

1.) ASSIGNMENT: As an American Peace Corps Volunteer I served two years as a reservoir management advisor to the Fisheries Department of Rajasthan State, Northwest India. Before embarking for India, I underwent a thirteen-week Peace Corps training program which included approximately five hundred hours of training in Fisheries. Our co-workers in India were Government Officers who had undergone two years of special training in fisheries in Bombay. Our roles therefore differed considerably from the usual stereotype of a Peace Corps "generalist."

2.) LIFE-STYLE: My life in India was split between my station on an isolated reservoir miles from the world of electric light bulbs and plumbing -- where I lived for months at a stretch without hearing a word of English -- and the maze of government offices through which I guided my proposals.

3.) WORK: I worked as a virtually unsupervised "idea man", starting an applied research program on the fish populations in a four-square mile reservoir, and writing proposals for changes in management practices. Eighteen papers and notes containing my proposals were published in mimeograph form by the American Peace Corps Office in New Delhi; these will shortly be printed, along with the work of other volunteers, as a Handbook on North Indian Reservoir Management.

4.) SUCCESSSES: Several of my ideas on Rajasthan fisheries had been accepted by the Department at the time of my departure in September, 1971. The most important of these included:

a.) common carp pilot study: The exotic species Cyprinus carpio was being introduced on a large scale into reservoirs in Northern India despite some indications that it might compete with more desirable species of native carps. The fisheries directors in two states, Rajasthan and Madhya Pradesh, had agreed at the time of my departure to halt the stocking of common carp in large reservoirs and restrict stocking to small tanks in which the Indian species did not naturally breed, pending the outcome of a pilot study which I designed.

b.) base rate system: This system would change the way in which royalties were collected from fisheries contractors in such a way as to eliminate the contractor's economic incentive for taking only a few of the more valuable species and leaving the rest. Such selective fishing, if allowed to continue, would eventually have caused the reservoir to become overrun with trash fish. A marked decline in the most valuable species was already taking place. At the time of my departure this proposal had passed through the entire hierarchy of the Fisheries Division and Animal Husbandry Department, and had been

forwarded by the Deputy Secretary to the Minister of Agriculture. If he approved it as planned, the system was to be instituted on a trial basis this year at the Bundh Baretha Reservoir, as a prelude to its introduction in reservoirs throughout Rajasthan.

F.) SPECIAL QUALIFICATIONS:

1.) FLUENT HINDI:

I speak simple conversational Hindi well enough to converse without feeling restricted by the language. Languages come easily to me: after the first few months of my Peace Corps work I spoke only Hindi when speaking with North Indians, including my dealings with Government Officers who had large English vocabularies. This is a rarity among Peace Corps Volunteers in India.

2.) BROAD EDUCATIONAL BACKGROUND:

My undergraduate career in a special honors Independent Study Program sponsored by the Ford Foundation lead to much more work in the social sciences than characterizes most biology majors. A tour as President of the Colorado College International Relations club, plus leading "anthropology workcamps" to the Cherokee Indians of Oklahoma and the Tarahumaras of Mexico added to this broadening. This is not to say that I have not also prepared myself well in my specialty of ecology.

3.) CROSS-CULTURAL SKILL:

I have developed a certain skill in working with people of other cultures through a long history of work with such diverse peoples as American Indians, Slash-and-burn agriculturists in Costa Rican rainforest, and my Peace Corps work which involved dealing with persons ranging from the lowest of laborers to powerful Government officials. I have also traveled in over 40 countries in North, Central and South America, East, Central, West and North Africa, Europe, and South Asia.

I regard my cross-cultural skill as one of my most important qualifications for carrying out the work outlined in this proposal.

G.) BIBLIOGRAPHY OF THE PRINCIPAL INVESTIGATOR:

Fearnside, Philip M., 1970a. report on work done at Bundh Baretha, (mimeo) American Peace Corps, New Delhi.

\_\_\_\_\_, 1970b. Plan for a rotenone cove sample in Bundh Baretha, (mimeo) American Peace Corps, New Delhi.

\_\_\_\_\_, 1970c. Reasons for abandoning the Bundh Baretha Fish Farm, (mimeo) American Peace Corps, New Delhi.

\_\_\_\_\_, 1971a. Procedure and need for collection of Royalty fishing data at Bundh Baretha, (mimeo) American Peace Corps, New Delhi.

\_\_\_\_\_, 1971b. Procedure and need for collection of sample netting data at Bundh Baretha, (mimeo) American Peace Corps, New Delhi.

\_\_\_\_\_, 1971c. A method for estimating the standing crops and species compositions of reservoirs using sample netting and a rotenone cove sample illustrated with sample netting data from Bundh Baretha, 14 October 1969 - 20 January 1971, (mimeo) American Peace Corps, New Delhi.

\_\_\_\_\_, 1971d. Proposed improvements of watch and ward arrangements to prevent illegal fishing in Rajasthan reservoirs, (mimeo) American Peace Corps, New Delhi.

\_\_\_\_\_, 1971e. A guide to the base-rate system for prospective royalty contractors, (mimeo) American Peace Corps, New Delhi, (English and Hindi)

\_\_\_\_\_, 1971f. The base-rate system for setting royalties for commercial fishing at Bundh Baretha, (mimeo) American Peace Corps, New Delhi.

\_\_\_\_\_, 1971g. The base-rate system: objections answered, (mimeo) American Peace Corps, New Delhi.

\_\_\_\_\_, 1971h. Proposal for negotiating a minimum water-level agreement for Bundh Baretha, (mimeo) American Peace Corps, New Delhi.

\_\_\_\_\_, 1971i. Plan for a study of major carp spawning and recruitment in the Bundh Baretha Reservoir, District Bharatpur (Rajasthan), (mimeo) American Peace Corps, New Delhi.

\_\_\_\_\_, 1971j. Suggested design for boat to be purchased for Bundh Baretha Fisheries Project, (mimeo) American Peace Corps, New Delhi.

\_\_\_\_\_, 1971k. Plan for a pilot study to assess the effect on major carp populations of introducing common carp (*Cyprinus carpio*) into Rajasthan reservoirs, (mimeo) American Peace Corps, New Delhi.

\_\_\_\_\_, 1971l. Proposal for establishment of small field library for fisheries research at Bundh Baretha, (mimeo) American Peace Corps, New Delhi.

\_\_\_\_\_, 1971m. Disadvantages of a long-term contract for Bundh Baretha, (mimeo) American Peace Corps, New Delhi.

\_\_\_\_\_, 1971n. Comments on Ambala Fish Seed Farm (Haryana), (mimeo) American Peace Corps, New Delhi.

\_\_\_\_\_, 1971o. Comments on Saidpur Fish Seed Farm (Haryana), (mimeo) American Peace Corps, New Delhi.

\_\_\_\_\_, 1973a. an estimate of the carrying capacity of the Osa Peninsula for human populations supported on a shifting agriculture technology, (in press) Report of Research Activities Undertaken during the Summer of 1972, Organization for Tropical Studies, San Jose, Costa Rica.

\_\_\_\_\_, 1973b. observations on farming and ranching techniques employed at Finca La Pacifica, Guanacaste, (in Press) Report of Research Activities Undertaken During the Summer of 1972, Organization for Tropical Studies, San Jose, Costa Rica.

Reprints of any of the American Peace Corps writings can be supplied on request.

VII.) BUDGET:

A.) PAYMENTS TO BE MADE DIRECTLY TO INTERNATIONAL CARRIERS:

1.) International Travel:

Detroit - Washington, D.C.

-- New Delhi -- Detroit U.S. \$ equiv. 1366.00

2.) International transport of things:

10 kgs. @ U.S. \$ equiv. 11.09/Kg.  
(personal effects, including typewriter) U.S. \$ equiv. 110.90

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total to Int'l. carriers U.S. \$ equiv. 1476.90

B.) PAYMENTS TO BE MADE DIRECTLY TO GRANTEE REPRESENTATIVE IN INDIA:

1.) living allowance:

a.) Delhi: 6 days @ U.S. \$ equiv. 21  
U.S. Gov't. per diem rate.  
(Sept. 4 - 9) U.S. \$ equiv. 126.00

b.) Outside Delhi: 57 days @ U.S.  
\$ equiv. 16 U.S. Gov't per  
diem rate  
(July 8 - Sept. 3) U.S. \$ equiv. 912.00

2.) travel in India:

a.) Indian Airlines  
Jaipur - Jodhpur U.S. \$ equiv. 12.50  
Jodhpur - Jaipur U.S. \$ equiv. 12.50  
Jaipur - Delhi U.S. \$ equiv. 11.20

b.) Indian railways and busses:  
1000 km @ U.S. \$ equiv.  
0.03/km U.S. \$ equiv. 30.00

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total directly to  
grantee representative U.S. \$ equiv. 1104.20

C.) BUDGET TOTAL:

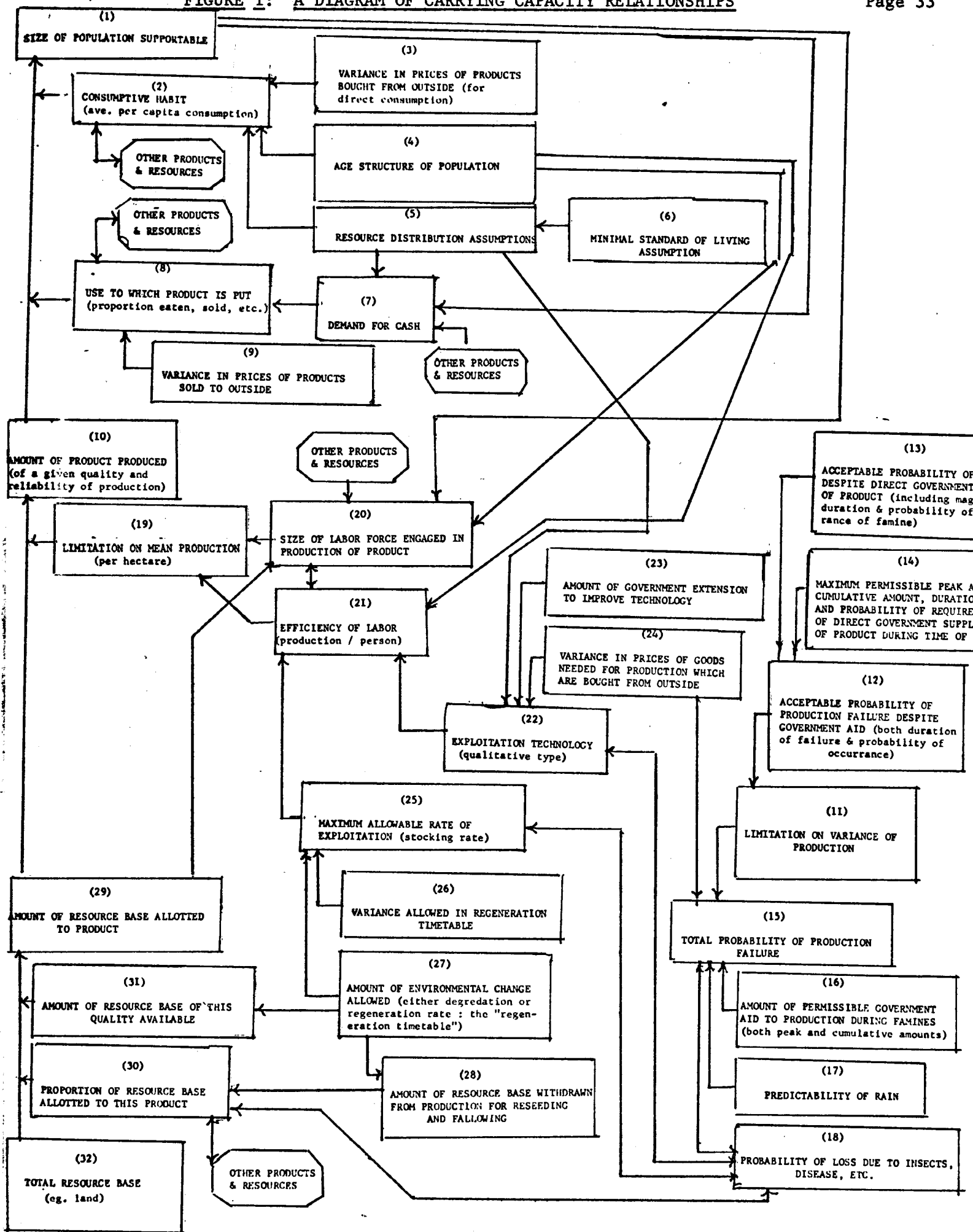
1.) exchange rate:

U.S. \$1.00 = Rs. 7.60

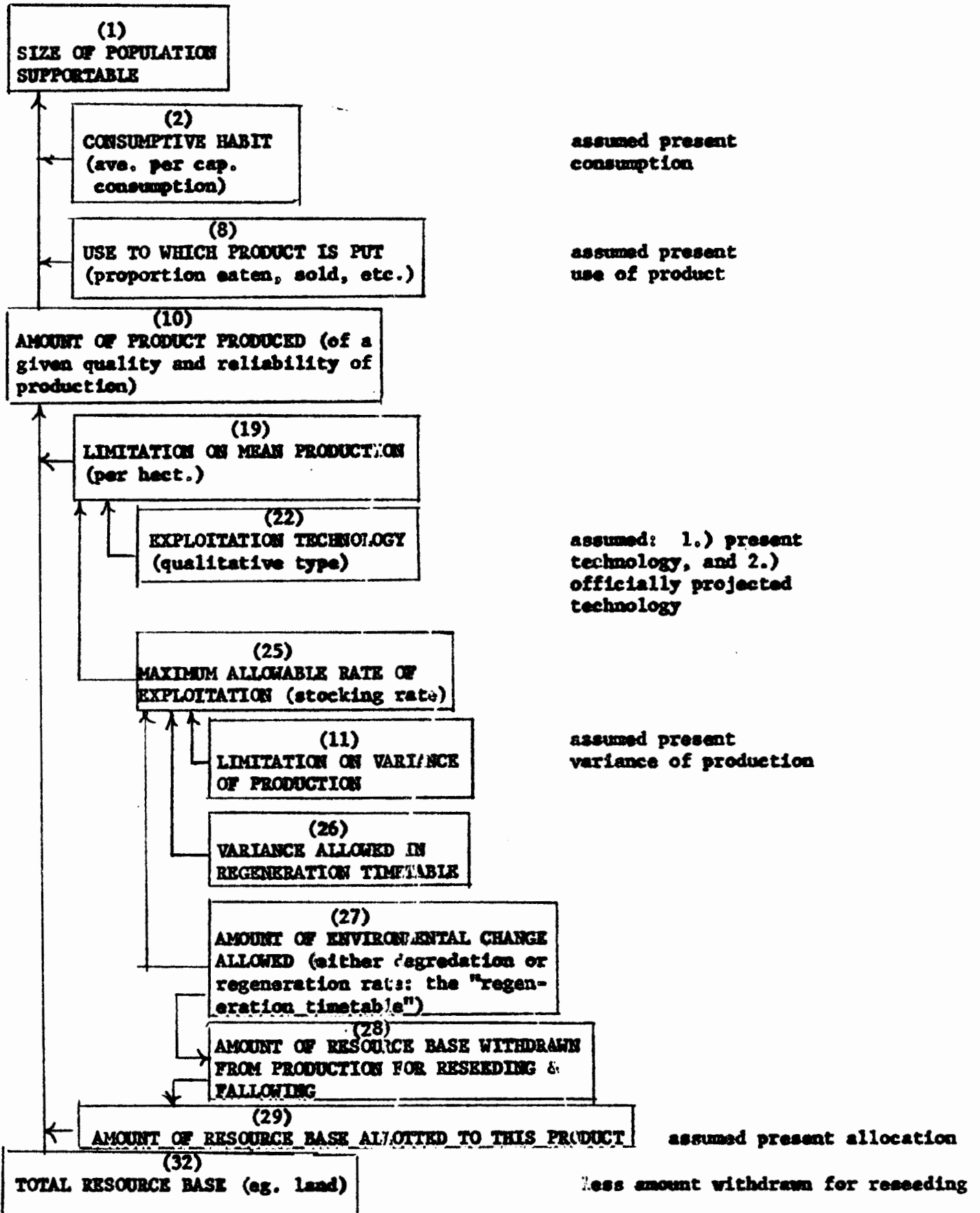
2.) Total budget: U.S. \$ equiv. 2581.10

**D.) NO FOREIGN EXCHANGE (U.S. \$) REQUESTED:**

It should be noted that no payments are requested in U.S. dollars, and all payments are requested in Indian Rupees. All funds are to come from the Smithsonian / Foreign Currency Program; no money is requested from the Indian Government or any other institution. This proposal has not been submitted to any other funding agency.



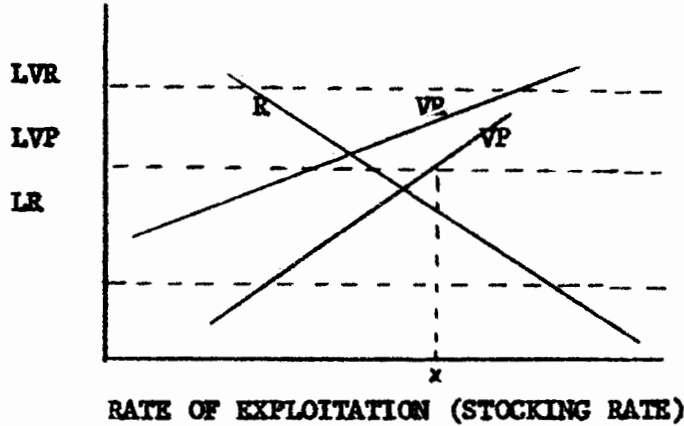
**FIGURE 2: THE BARE BONES; A DIAGRAM OF CARRYING CAPACITY RELATIONSHIPS WITH VARIOUS SIMPLIFYING ASSUMPTIONS**



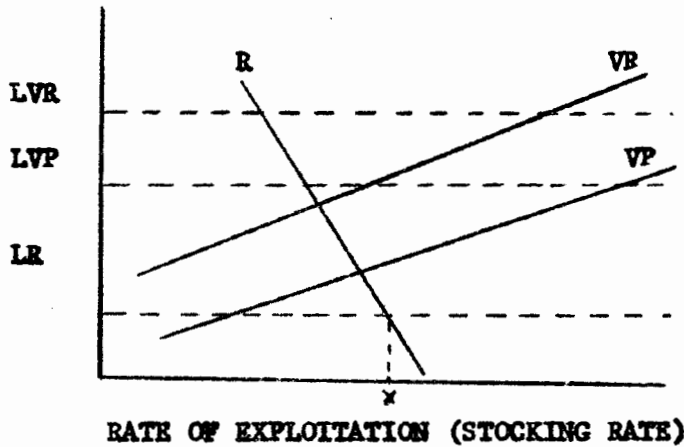
**FIGURE 3: POSSIBLE RELATIONSHIP BETWEEN FACTORS DETERMINING THE MAXIMUM ALLOWABLE RATE OF EXPLOITATION (STOCKING RATE)**

- R = amt. environmental change (regeneration rate)
- VR = variance of regeneration rate
- VP = variance of production
- LVP = limitation on variance of production contributed by stocking rate
- LVR = limitation on variance of regeneration time table
- LR = minimum allowed amt. of enviro. change (regeneration rate)

**OUTCOME I: VARIANCE OF PRODUCTION LIMITING**



**OUTCOME II: REGENERATION RATE LIMITING**



**OUTCOME III: VARIANCE OF REGENERATION TIME TABLE LIMITING**

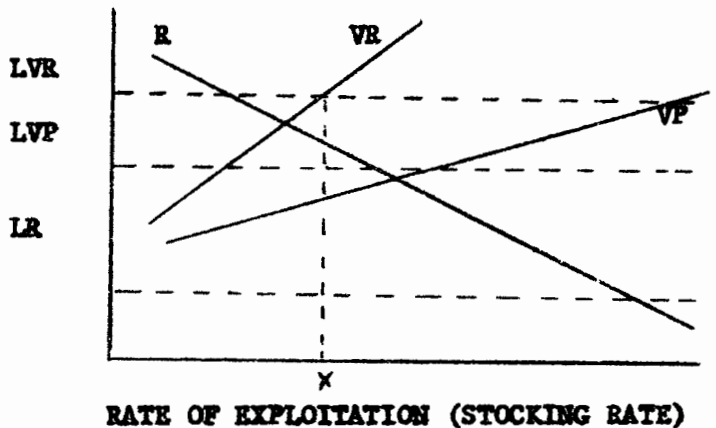
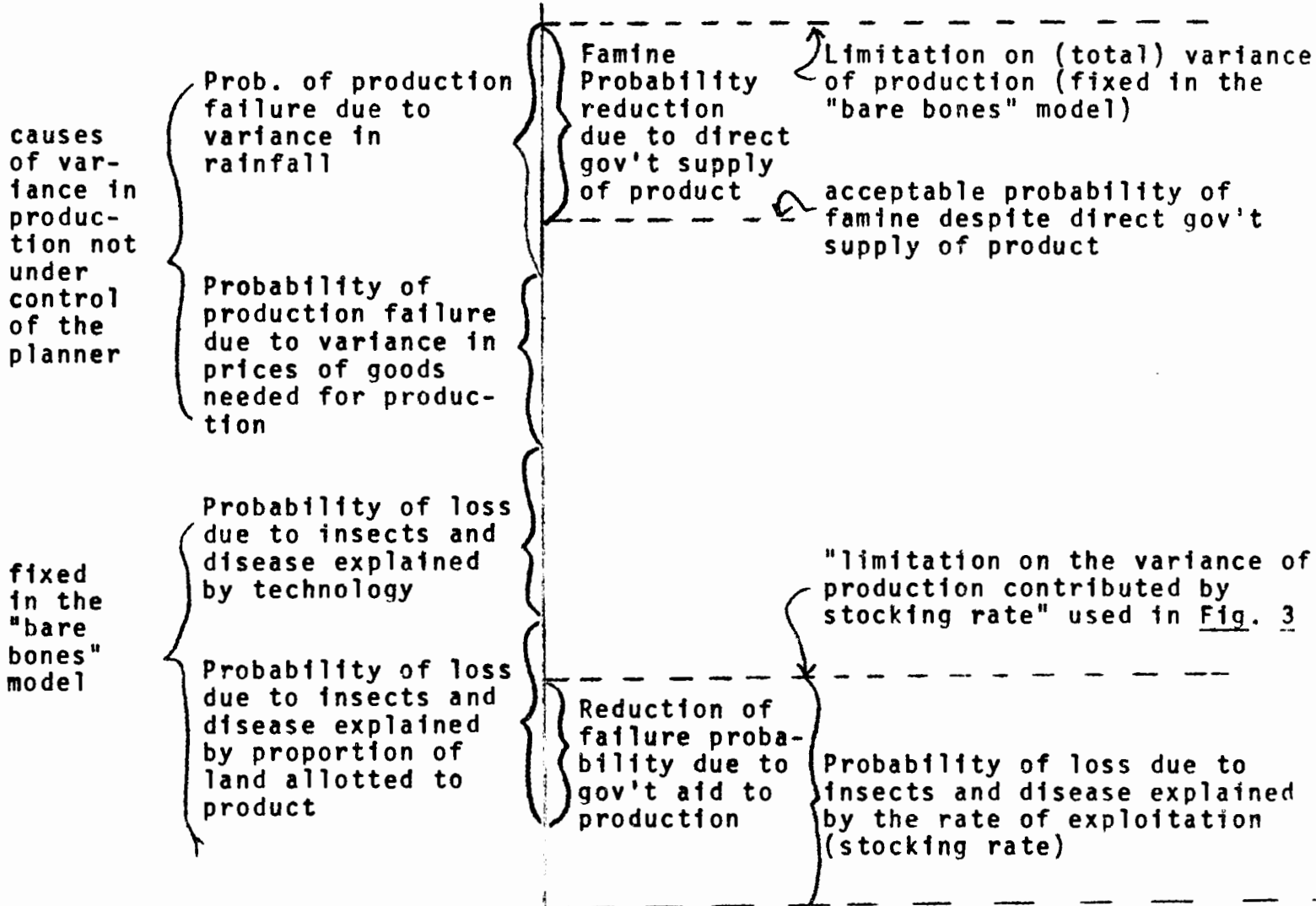
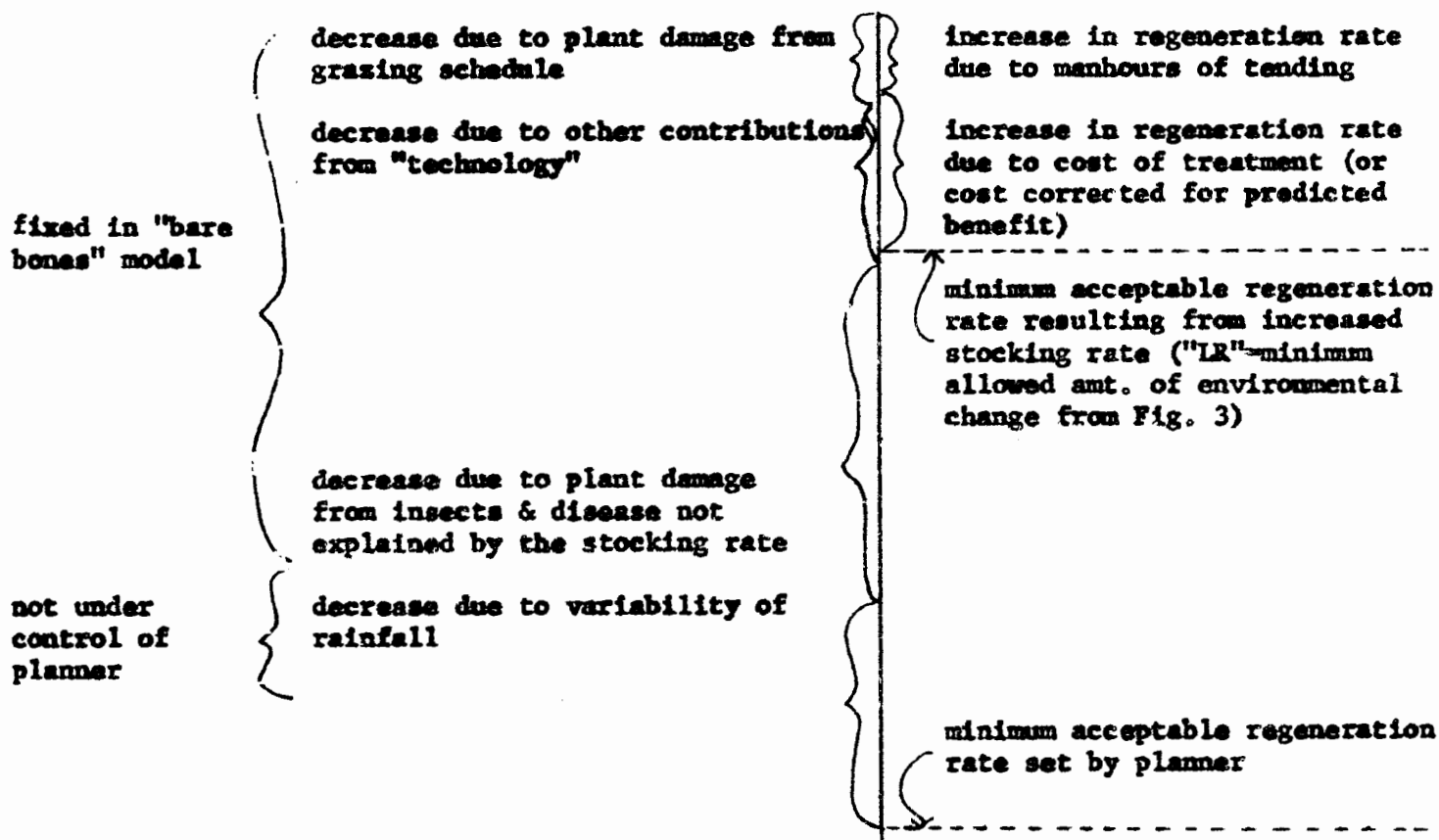


FIGURE 4: DERIVATION OF THE LIMIT ON VARIANCE OF PRODUCTION FOR THE "BARE BONES" MODEL:



**FIGURE 5: DERIVATION OF THE LIMITATIONS ON THE CONTRIBUTION TO THE DECREASED MEAN OF THE REGENERATION RATE DUE TO THE STOCKING RATE**



**FIGURE 6: DERIVATION OF THE LIMITATIONS ON THE CONTRIBUTION TO THE VARIANCE OF THE REGENERATION RATE DUE TO THE STOCKING RATE**

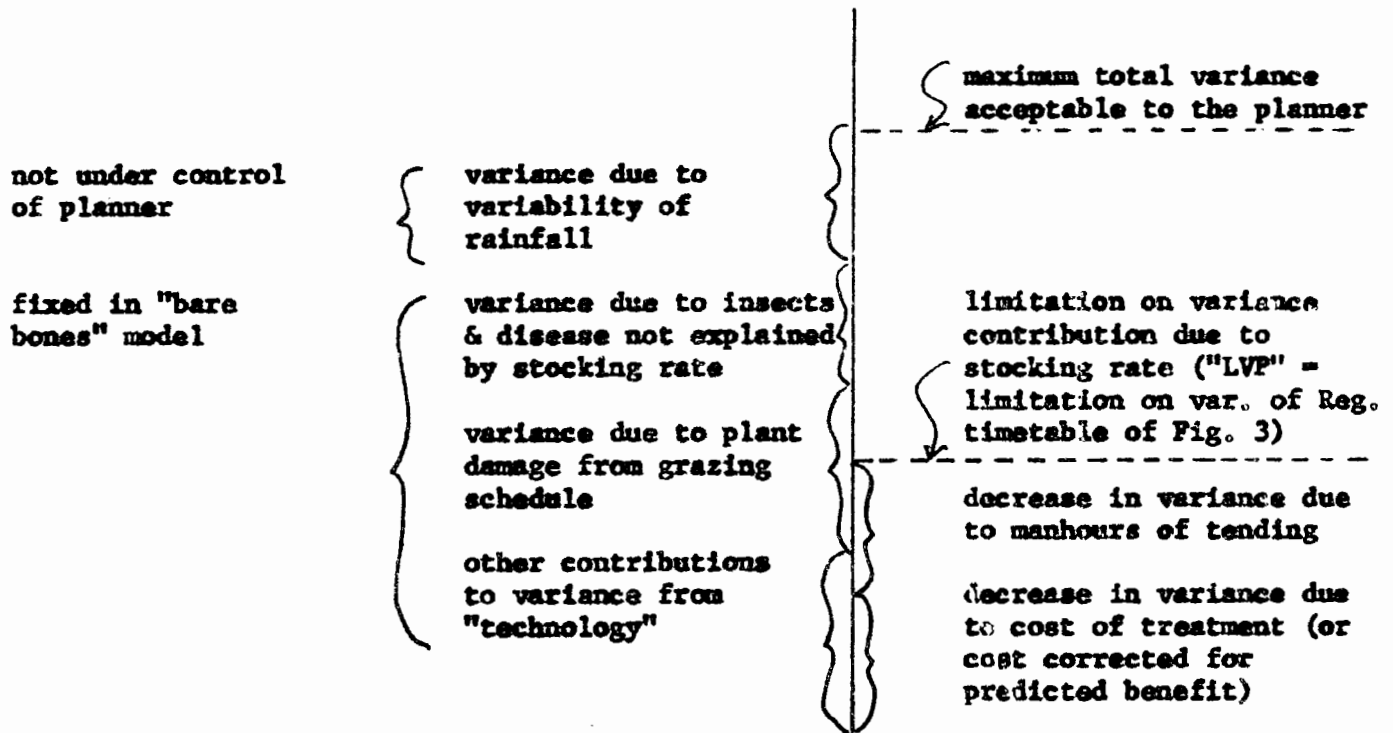


TABLE 1 : EXPLANATION OF COMPONENTS AND LINKS IN THE MODEL SHOWN IN FIGURE 1

COMP.  
NO.COMPONENT  
(shown in the  
boxes in Fig. 1)DEFINITION OF  
COMPONENTPOSSIBLE  
ASSUMPTIONS  
ABOUT COMPONENTPOSSIBLE DATA  
SOURCES FOR  
ASSUMED VALUE  
OF COMPONENTLINKS TO OTHER COMPONENTS  
(shown by arrows leading  
away from the component  
in Fig. 1)

(1)	size of population supportable  ("carrying capacity")	No. of persons supportable on local resources for an indefinite time period given the assumptions described below as to consumptive habit (ie. "standard of living") technology, resource allocation, rate of environmental change, and variance tolerances about each of these.	none  (dependent variable)	--	To: size of labor force: direct relation, the labor force size for production of a given product being dependent on the population size, age structure, <del>and</del> the demands for labor for production of other products, and the amt. of resource base allotted for production of the product.
(2)	consumptive habit  ("standard of living" term)	the average amount consumed directly per person, given the restriction on the variance of consumption (which has been translated into a restriction on the variance of production)	1.) present consumption  2.) minimal standard of living restriction  3.) "optimal" resource distribution	1.) socio-economic surveys  2.) official poverty line  3.) arbitrary	To: size of population supportable: Amt. of product produced X proportion consumed directly / average per capita consumption = population supportable (note that the "amount produced includes variance restrictions)

COMPONENT NUMBER	COMPONENT (shown in boxes in Fig. 1)	DEFINITION OF COMPONENT	POSSIBLE ASSUMPTIONS ABOUT COMPONENT	POSSIBLE DATA SOURCES FOR ASSUMED VALUE OF COMPONENT	LINKS TO OTHER COMPONENT (shown by arrows leading away from the component in Fig. 1)
(3)	variance in prices of products bought from outside	the "products" here refers to goods bought for direct consumption, such as food.	present price fluctuation levels	economic records of recent years	To: Consumptive habit! High variability may affect how much the population will satisfy its needs locally and how much it will rely on cash cropping and exchange
(4)	age structure of population	the proportion of the population in each age class	1) present age structure 2) stable age distribution	1) census data 2) calculated	To: Size of labor force the number of persons in the age groups producing the product, adjusted for the demands for producing other products  To: efficiency of labor force: the efficiency of each age class will differ

COMPONENT NUMBER (	COMPONENT (shown in boxes in Fig. 1)	DEFINITION OF COMPONENT	POSSIBLE ASSUMPTIONS ABOUT COMPONENT	POSSIBLE DATA SOURCES FOR ASSUMED VALUE OF COMPONENT	LINKS TO OTHER COMPONENT (shown by arrows leading away from the component in Fig. 1)
(5)	resource distribution assumptions	this can be measured through such measures as the "evenness" term of species diversity formulas using the proportions of the population in each income class or proportions in classes determined by amt and quality of land owned	1) present 2) minimal std. of living 3) optimal	1) socio-econ studies + gov't data 2) official poverty line 3) arbitrary	To: consumptive habit: the consumption of the product in question by each income category  To: exploitation technology: the probability of adopting technological changes will differ for each income category
(6)	minimal standard of living assumptions	The monthly per capita income below which no member of the population would be allowed to fall.	1) none 2) set arbitrarily	1) --- 2) official poverty line	To: resource distributions: this will truncate the lowest income classes
(7)	demand for cash	the amount of cash income needed by the population to satisfy their demands for products (to be directly consumed) and goods (to be used in production) which are brought from outside	1) present demand from each income category 2) projected demand with projected changes in technology	1) socio-econ data 2) projected	To: use to which product is put: this will determine the ratio of cash cropping to subsistence farming

COMPONENT NUMBER	COMPONENT (shown in boxes in Fig. 1)	DEFINITION OF COMPONENT	POSSIBLE ASSUMPTIONS ABOUT COMPONENT	POSSIBLE DATA SOURCES FOR ASSUMED VALUE OF COMPONENT	LINKS TO OTHER COMPONENT (shown by arrows leading away from the component in Fig. 1)
(8)	use to which product is put	the proportion of the production which is eaten, sold, etc.	present use pattern	gov't data	To: size of supportable population: proportion consumed directly x amt of product produced / average amt required per capita = size of supportable population based on this product
(9)	variance in prices of products sold to outside	fluctuation in the prices received for cash crops sold	present	gov't data	To: use to which product is put: high variance may discourage cash cropping
(10)	amount of product produced	the amount of the product given the restrictions on the quality of the product and the reliability of its production	none (dependent variable)	----	To: size of population supportable: amt of product produced X proportion consumed directly / average per capita consumption = size of population supportable based on this product
(11)	limitation on variance of production	the maximum amt of variability in production acceptable. Other components in the system must be adjusted in such a way as to produce no more than this amt of variability	1) present observed 2) calculate from gov't goals	1) gov't production re- 2) gov't policy statements	To: total probability of production failure: the total probability of production failure must not exceed this limit

COMPONENT NUMBER	COMPONENT (shown in boxes in Fig. 1)	DEFINITION OF COMPONENT	POSSIBLE ASSUMPTIONS ABOUT COMPONENT	POSSIBLE DATA SOURCES FOR ASSUMED VALUE OF COMPONENT	LINKS TO OTHER COMPONENTS: (shown by arrows leading away from the component in Fig. 1)
(12)	acceptability probability of production failure despite gov't aid	the total probability of a production failure, including its duration and the probability of its occurrence which the planner is willing to accept	1) present probability of production failure 2) set arbitrarily	1) history of recent production failures 2) gov't goals	To: limitation on variance of production: variance of production must not exceed this limit
(13)	acceptable probability of famine despite direct gov't supply of product	the probability acceptable to the planner, including the magnitude, duration, and probability of occurrence of famine	1) present probability 2) set arbitrarily	1) history of recent famines 2) gov't goals	To: acceptable probability of production failure despite gov't aid: acceptable probability of production failure = acceptable prob. of famine + max. permissible peak & cumulative amt, duration and probability of requirement of direct gov't supply of product
(14)	maximum permissible peak and cumulative amt, duration and probability of requirement of direct gov't supply of product	the amount acceptable to the planner	1) present level 2) ideal level	1) gov't records of recent famine relief operations 2) from goals of gov't planners	To: acceptable probability of production failure despite gov't aid: as in #13

COMPONENT NUMBER	COMPONENT (shown in boxes in Fig. 1)	DEFINITION OF COMPONENT	POSSIBLE ASSUMPTIONS ABOUT COMPONENT	POSSIBLE DATA SOURCES FOR ASSUMED VALUE COMPONENT	LINKS TO OTHER COMPONENTS (shown by arrows leading away from the component in Fig. 1)
(15)	total probability of production failure	a measure of the variance of production. This includes the probability of occurrence of a failure, together with the probable duration and magnitude of the lowered production	1) present variability 2) ideal variability	1) gov't records of production 2) goals of gov't planners	To: probability of loss due to insects, disease, etc.: prob. of loss due to insects, etc. must be low enough to bring the total prob. of production failure below the limit set by the planner (see P. 9 of text)
(16)	amt of permissible gov't aid to production during famines	amt acceptable to gov't planners. Includes both peak and cumulative amounts, as well as the probability of requirement	1) present level 2) ideal level (set arbitrarily)	1) recent history of gov't aid to production 2) gov't goals	To: total probability of production failure: cushions prob. of production failure (see Fig. 4)
(17)	predictability of rain	the variability in rainfall (both in amount and timing, as related to production)	present	weather records	To: total probability of production failure: direct relation to production (see Fig. 4)
(18)	probability of loss due to insects, disease, etc.	a measure of the variance in production explained by these factors	1) present 2) projected under assumed stocking rate, etc.	1) gov't records 2) experimental or other data from gov't records	To: max. allowable rate of exploitation (stocking rate): explained in Figs. 3 & 4 To: exploitation technology: derived in a way similar to the stocking rate.

COMPONENT NUMBER	COMPONENT (shown in boxes in Fig. 1)	DEFINITION OF COMPONENT	POSSIBLE ASSUMPTIONS ABOUT COMPONENT	POSSIBLE DATA SOURCES FOR ASSUMED VALUE COMPONENT	LINKS TO OTHER COMPONENTS: (shown by arrows leading away from the component in Fig. 1)
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(18) Continued

New technologies, such as high-yielding livestock breeds with reduced resistance to disease, could be expected to produce different variabilities in production through disease rate changes

To: proportion of resource base allotted to production of this product: similar to stocking rate derivation; large monocultures have higher probability of failure due to insects, etc.

(19)	limitation on mean production	maximum mean production per hectare given the constraints on regeneration, variances, etc.	none (dependent variable)	----	To: amount of product produced: $\text{amt of product produced} = \text{mean production per hectare} \times \text{amt of resource base allotted to this product}$
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(20)	size of labor force engaged in production	number of persons and proportion of their time spent in producing the product	----	calculate from age structure & pop. size together with effective resource availability, the efficiency of labor,	To: efficiency of labor: probably a modal relation with a positive relation at low densities of population and a negative relation at high densities
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COMPONENT NUMBER	COMPONENT (shown in boxes in Fig. 1)	DEFINITION OF COMPONENT	POSSIBLE ASSUMPTIONS ABOUT COMPONENT	POSSIBLE DATA SOURCES FOR ASSUMED VALUE COMPONENT	LINKS TO OTHER COMPONENTS: (shown by arrows leading away from the component in Fig. 1)
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(20) Continued

and the demands for labor for other products To: limitations on mean production: linked directly - mean production per hectare = size of labor force X production per person (note that the size of the labor force is limited by the availability of the resource)

(21) efficiency of labor the production per person

1) present  
2) project from age structure, technology, stocking rate, and labor force size

1) gov't prod. records & socio-econ data  
2) projections To: limitations on mean production: mean production per hect. = size of labor force producing the product X efficiency (note that the size of the force is limited by the resource availability and the efficiency is limited through the technology and the stocking rate to the various variance restrictions)

To: size of labor force: labor force size could either be set to maximize efficiency, or a modification of this if a larger-than-maximally-efficient population were desired for other reasons

COMPONENT NUMBER	COMPONENT (shown in boxes in Fig. 1)	DEFINITION OF COMPONENT.	POSSIBLE ASSUMPTIONS ABOUT COMPONENT	POSSIBLE DATA SOURCES FOR ASSUMED VALUE COMPONENT	LINKS TO OTHER COMPONENTS: (shown by arrows leading away from the component in Fig. 1)
(22)	exploitation technology	the qualitative type of the technology (such as the breed of livestock) as opposed to the quantitative aspect (such as the stocking rate)	1) present technology 2) projected technology	1) gov't records 2) gov't projections	To: efficiency of labor: usually a direct positive relation in terms of production / man-hour, although often not in terms of energy  To: probability of loss due to insects, disease, etc.: usually probability of loss would increase with increased reliance on exotic cultivars, high-yielding breeds, etc.
(23)	amount of gov't extension to improve technology	the expenditure by the gov't (or aid-giving agencies, etc) to both developed improved production technology and to convince local residents to use it	1) present extension effort level 2) projected level	1) gov't records 2) five-year plans & other development schemes	To: exploitation technology: positive relation, although not necessarily linear
(24)	variance in prices of goods needed for production which are bought from outside	a measure of the amt of fluctuation in the prices of goods bought	present variance	econ lit and gov't records	To: exploitation technology: increased variance in prices of goods should lead to decreased tendency to adopt new technology  To: total probability of production failure:

Table 1: P.

Page 48	COMPONENT NUMBER	COMPONENT (shown in boxes in Fig. 1)	DEFINITION OF COMPONENT	POSSIBLE ASSUMPTIONS ABOUT COMPONENT	POSSIBLE DATA SOURCES FOR ASSUMED VALUE COMPONENT	LINKS TO OTHER COMPONENTS: (shown by arrows leading away from the component in Fig. 1)
	(24)	Continued				increased variance of prices should lead to increased probability of production failure. The importance of price fluctuations should increase as the technology becomes more "advanced" and more dependent on outside supply of goods
	(25)	maximum allowable rate of exploitation (stocking rate)	the rate at which the resource can be utilized, such as the number of goats per hectare of land or per quintal of fodder production	none (dependent variable)	----	To: efficiency of labor: labor should be least efficient at extremely low and extremely high stocking rates, and most efficient at some intermediate rate/ The stocking rate is related to the mean production through the efficiency of labor
	(26)	variance allowed in regeneration timetable	the amount of variability acceptable to the planner in the rate of regeneration	arbitrary	goals of gov't planners	To: maximum allowable rate of exploitation (stocking rate): See Figs 3 & 6 and the discussion on P. 10-12

COMPONENT NUMBER	COMPONENT (shown in boxes in Fig. 1)	DEFINITION OF COMPONENT	POSSIBLE ASSUMPTIONS ABOUT COMPONENT	POSSIBLE DATA SOURCES FOR ASSUMED VALUE COMPONENT	LINKS TO OTHER COMPONENTS: (shown by arrows leading away from the component in Fig. 1)
(27)	amt of environmental change allowed (regeneration timetable)	the average rate of environmental improvement deemed necessary by the planner	arbitrary	goals of gov't planners	<p>To: maximum stocking rate: see Figs. 3 &amp; 5 and discussion on P. 11-12</p> <p>To: amt of resource base withdrawn from production for reseeding and fallowing: a requirement for a speedier regeneration of the desert will require more land be withheld from production</p> <p>To: amt of resource base of this quality available: over time the regeneration program will reduce the amt of land in the poorer quality classes and increase the amt in the better classes (the opposite would be true, of course, if the "environmental change" allowed were degeneration rather than regeneration)</p>
(28)	amt of resource base withdrawn from production	the area of land temporarily taken out of production as a part of the regeneration program	arbitrary (governed by the desired regeneration rate)	regeneration experiments of C.A.Z.R.I.	To: proportion of resource base allotted to this product: proportion allotted to this product = one - the proportion

COMPONENT NUMBER	COMPONENT (shown in boxes in Fig. 1)	DEFINITION OF COMPONENT	POSSIBLE ASSUMPTIONS ABOUT COMPONENT	POSSIBLE DATA SOURCES FOR ASSUMED VALUE COMPONENT	LINKS TO OTHER COMPONENTS: (shown by arrows leading away from the component in Fig. 1)
(28)	Continued				subjected to other products and uses - the proportion withheld as part of the regeneration program.
(29)	amt of resource base allotted to production of this product	the number of hectares of land used for goat grazing, for example	1) present amt, present allocation 2) an optimal allocation which minimizes the probability of loss to insects, disease, etc. while still satisfying minimal production requirements	1) C.A.Z.R.I & other surveys, gov't records 2) derived experimentally	To: size of labor force: the size of labor force engaged in production of a product must depend directly on the amt of resource available for exploitation. The labor force should not be larger than needed unless the decreased resulting efficiency can be balanced by gains in terms of other goals  To: amount of product produced: amt produced = no. of hectares X mean production per hectare.
(30)	proportion of resource base allotted to this product	the proportion of the amt of resource base of this quality available which is used for production of this product		1) C.A.Z.R.I. land surveys	To: amount of resource base allotted to this product: amt allotted = amt available X proportion allotted  To: probability of loss

COMPONENT NUMBER	COMPONENT (shown in boxes in Fig. 1)	DEFINITION OF COMPONENT	POSSIBLE ASSUMPTIONS ABOUT COMPONENT	POSSIBLE DATA SOURCES FOR ASSUMED VALUE COMPONENT	LINKS TO OTHER COMPONENTS: (shown by arrows leading away from the component in Fig. 1)
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(30) Continued

ease, etc:  
 increased proportion allotted to one product leads to increased probability of loss and to an increased magnitude of loss when it occurs

(31)	amt of resource base of this quality available	the amt of the total resource base which falls into the quality category being considered  (calculations will, of course, be summed over all quality categories)	1) present amt of res base  2) projected amt after beginning of regeneration program	1) C.A.Z.R.I. land surveys  2) projected from regeneration rate	To: amount of resource base allotted to this product: amt allotted = amt available X proportion allotted
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(32)	total resource base	the total amount of land of all qualities available	present	land surveys	To: amt of resource base allotted: through the amt of res base of each quality available
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TABLE 2SOME FEATURES OF THE RAJASTHAN DESERT:

FEATURE	REFERENCE
1.) dust: dustiest of all deserts	Bryson, 1972
2.) rainfall: 120 mm/yr in west to 400 mm/yr with high variance	Kaul & Chakravarty, 1968
3.) relative humidity: 93% in August to 10% in April & May	Kaul & Chakravarty, 1968
4.) average wind velocity: 3km/hr in Dec. & Jan. to 32 km/hr in April & May	Kaul & Chakravarty, 1968
5.) temperature: ranges from below 0°C. in winter to 50°C. in summer	Kaul & Chakravarty, 1968
6.) dew point: high during summer, and many clouds	Bryson, 1972
7.) most densely populated desert in world	Bryson, 1972
8.) barrenness: region more barren than rainfall would lead one to predict	Bryson, 1972
9.) livestock populations:	Anonymous, 1964
cattle : 4.74 mill.	
sheep : 5.66 mill.	
goats : 3.38 mill.	
other : 0.50 mill.	

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