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ABSTRACT

Nepal's hill region suffers from critical shortages of food, forage and fuelwood. The impact of this increasingly severe problem is being felt in terms of rapid environmental deterioration. The problems are manifold and interrelated.

This study is therefore designed to carry out a whole system planning which includes an environmental component. A watershed level management plan is suggested for Phewa Tal Watershed in central Nepal which considers interactions among resources and aims at reducing soil erosional problems. To seek decentralization in the planning process, a multi-level planning approach is used.

Linear programming is applied as the analytical tool. Models are formulated at two levels: lower (single) level models for Panchayats (village councils) and a higher (multi) level model for the whole watershed. A single level model designated as the basic model aims at allocating the resources of each Panchayat to various management activities in an optimal manner. As a single plan maximizing gross profit margin meeting all the constraints is not feasible, five alternative management plans are prepared for each of six Panchayats. These plans are comprised of 34 output items treated for a typical year, averaging 15 years of planning horizon.

The watershed level model is then constructed with 30 Panchayat level plans acting as decision variables. Only 27 output items are

considered in this model as the remaining seven items are of a minor nature. The watershed level targets are fixed, based on the survey results obtained through various studies conducted during the last few years. Alternative plans are formed from criteria based on the recommendations of a currently adopted Phewa Tal Watershed Management Plan.

Constraints are constructed to force the selection of one alternative plan or a set of partial alternative plans per Panchayat. At the watershed level, constraints are used to maximize or minimize certain output items or the use of resource levels.

The maximization of the present gross value of selected alternative plans yields an infeasible solution when the constraints are enforced to meet: 1) all the watershed level target values for 27 output items, 2) minimum sediment production, and 3) maximum levels of budget, grant money, credit, labor, and compost. Seven watershed level alternative management plans are developed by setting up criteria reflecting the prioritized needs of local people and the environment.

The usefulness of an optimal resource allocation and multi-level planning approach to the Phewa Tal Watershed in particular and to Nepal in general can be seen in the: i) feasibility of formulating whole-system resource management approach, ii) possibility of improving the production of basic human needs, iii) existence of the method for carrying out decentralized planning, and iv) applicability of mathematical programming in the management of the country's renewable natural resources. The problems associated with this approach are: i) lack of adequate data base, ii) lack of computer facilities, iii) failure of this approach to accommodate socio-political considerations, iv) lack of planning capabilities at the Panchayat levels, and v) involvement of a high degree of uncertainty.

At a time when the government is stressing people's participation in planning and managing the country's natural resources in an environmentally sound manner, this work can be considered a useful guide for the concerned users.

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CHAPTER I

INTRODUCTION

Background Information

Providing people with ingredients of material well being requires physical resources (land, water, energy, plants and minerals) and the supporting contribution of environmental processes. Among the physical resources land is central in importance. Land not only means physical space but is also characterized by the uses to which it is put. To many countries in the world, the land and its characteristics form their major natural resources -- better known as renewable natural resources. Nepal is one of such countries.

This kingdom of 14 million people and 141,000 sq. kilometers of land area, four-fifths of which is mountainous, presently suffers from severe misuse of natural resources. The economy is based on agriculture which employs over 90 percent of the male/female labor force and accounts for 60 percent of Gross Domestic Products and 80 percent of export earnings. For years agriculture production has failed to keep pace with population growth (2.3 percent). Per capita income is approximately $120 U.S. which places Nepal among the poorest of the least developed countries (USAID, 1980). Sixty percent of Nepal's population lives in the hills and mountains. The majority of these people (80 percent) cultivate an average of 0.4 hectares of land. Most of the hill population derive a significant portion of their income through livestock raising, forest farming and cottage industries supported by forest and scrublands. These people are precariously dependent on their natural environment and any negative change in the environment is critical to their survival.

Environmental changes are already causing increasing concern. Approximately one fourth of Nepal's forests have disappeared during the past 25 years -- 1 million hectares in the last decade alone. At this rate there will be no accessible forests in hill areas in 15 years and none in Tarai[1/] in 25 years (FAO, 1979).

The government has given high priority to renewable resource management in its sixth five year plan (1981-198[illegible]), which specifically addresses existing policies for land use, environmental restoration and conservation of natural resources (National Planning Commission Secretariate, 1979). In spite of these recent developments, achievements made so far have been unsatisfactory. Governmental efforts to introduce sound land use systems lack clear direction and are having little impact. These efforts have been too small in scope to treat a problem of an immense magnitude; they have been single pronged with narrow goals such as afforestation, resettlement, terrace improvement or construction of costly erosion control structures.

If the country's environmental problems were only an expression of human short-sightedness, then education and technical measures could easily be conceived and implemented to stop it. But to fight with the process occurring due to combined cause of nature and human activity inevitably brings us into contradiction with important human values,

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[1/] An extension of Indo-Gangetic Plain characterized by tropical to sub-tropical climate and fertile soils.

social structures and economic constraints. Also the pilage of man's natural environment is not the consequence of a single cause, neither could it be stopped by choosing one line of action; it is due rather to the interaction of innumerable natural and cultural factors. Given such a background, in order to regain an ecological balance between man and his environment we need to modify the whole organism of culture which has developed within a given environment. It is realistic to envisage the future of development of Nepalese hills in such dimensions. In this study an attempt has been made to work in this line.

Hill Eco-system

Hills in Nepal occupy about 85 percent of the total land area. About 8.5 million people live on approximately 1 million hectares of cultivated land of comparatively low fertility. The hill region of Nepal is characterized by an elaborate crop and livestock farming system where cultivated plants, forest trees, range vegetation and domesticated animals are integrated to generate the best possible mix of goods and services to fulfill the basic needs of the people. About 15% of the land area is composed of alpine meadows in the high hills (57%), open grazing land in the mid-hills (33%), and steppic grazing land in trans-himalayan zone (10%). Forest covers 31% of the area and about 28% is classified as wasteland. Only 7% is available for cultivation. Lands under forest and range are continuously converted into first agricultural land and finally to degraded (waste) land.

Animal husbandary is considered to be a major economic activity second only to crop farming in the mid-hills whereas it is the prime occupation of the high hills. There is excessive ruminant livestock population in the hills. Current estimates are 5.98 million cattle, 2.6 million buffalo, 0.56 million sheep, 3.65 million goats, 0.36 million pigs and 8.21 million poultry (Rajbhandari and Shah, 1981). The pressure of rapid human and livestock population growth have expressed themselves in the form of overgrazing, deforestation for firewood, and clearing of steep slopes for cultivation. The result has been an appalling increase in rates of erosion, primarily by water. Cultivated areas during the last decade (1970-1980) increased by 8.7%. Areas under all the major cereal crops registered a growth of more than 11% in the mid-hills. In the high hills, however, there was a decline of 2%. Fleming (1978) reported cultivation up to and beyond 60% slope at Phewa Tal Watershed (study area of this thesis) in mid-hills. Most of the arable lands are exclusively terraced; some of them are expertly managed and ecologically stable; but others are farmed continuously despite their waning productivity.

Forests are both extensively and intensively utilized for fuelwood and timber production, livestock grazing, forage and thatch grass cutting and for occasional extraction of fruits, nuts and timbers. Two-thirds of the forests are continuously grazed. Rocky terrains, steep barren slopes, weed invested shrubland, gullies and other deformed and inaccessible lands are constantly on the increase (7% during the last decade), a natural consequence of deforestation, overgrazing and faulty agricultural practices. About 60-70% of these lands are still used for grazing and other uses.

Hill eco-systems thus, to put in the words of Toffin (1976), have been severely affected in the last three decades with a rapid degradation of natural environment through deforestation, increasingly poor soils, overgrazing and natural calamities. Rajbhandari and Shah (1981) have projected an annual decline of 1.2% in forest and 0.5% in rangeland.

Current System of Resource Management

The situation of the Himalayan landscape has been discussed in every report on natural resource[2/] management in Nepal. Its exploitation is not wanton, but stems from understandable human needs and anxieties. People express themselves with an utmost reasoning about the way they utilize the resources around them. Forest and ranges are sources for some of the basic needs of life. Forage for animals, fuel for cooking, food for man and building materials for shelter, wild mushrooms, honey, wide varieties of tubers, fruits and nuts as human food, tree leaves, grasses and herbs as animal forage, shurbs as fencing materials, bamboo for several household purposes, vines to make ropes, thatch grasses for roofing and several plant parts as medicine are the range of products derived by the rural people. Tree leaves make up about 40% of the annual feed of buffalo and 25% for cattle. Animals are allowed to graze in most parts of the forest. This process along with man's own operation of cut and burn ultimately converts forest, range and shrubland into cultivated land. The objective is to increase food grain production.

To raise maximum amounts of foodgrains farmers employ multiple cropping alternatives. Multiple cropping is the growing of more than

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[2/] Natural resources refer mainly to land resources, soils, vegetation, climate, geology, topography, hydrology, other land uses, human and livestock population and social structures.

one crop on a single field within the same year. Crops are sequenced depending on the availability of resources and the local environmental factors. Increasingly complex and critical management decisions about each aspect of the production operation must be made as various physical and economic resources are stretched toward their maximum potential use leaving little room for errors. Even the so-called abundant labor resource needs to be managed critically. The "labor profile" and "bullock power profile" will change from each stage of growing season to next exhibiting peak demand at planting, early weeding and at harvest. For small farmers since it is not possible to meet labor demand for entire planting, weeding, or harvesting operations at the same time, they must spread the demand by staggering their plantings.

Cash is generally in short supply; therefore, its use is minimized as much as is possible. Involvement of inputs like chemical fertilizers, implements and machineries are decided after careful analysis. Economics does show overriding influence.

Impact of Past Development Efforts

Nepal has passed through five periodic plans. The Sixth - Five Year Plan started in 1981. In most of the previous plans, there have been massive investments in capital intensive and long-term projects. Investments in roads, power plants, education and large irrigation projects have constituted about two thirds of the total public sector investments since 1962-63 (Shah, 1981). In the Sixth Plan however, the emphasis has been towards directly productive activities such as agriculture and forestry, as significant numbers of infrastructural facilities have already been built and foreign donors are showing more diversified interests (National Planning Commission, 1979). The aim is to acquire returns on past investments.

How much this new emphasis will pay off is not clear. If past trends are any indication, the prospect is poor. The trends in agricultural productivity over the past twenty years show how little the government could achieve even by investing in the so-called directly productive activities. The data in Table 1.1 shows that since 1961-62 there has been a significant increase in agricultural inputs, including irrigation water; however, the yield per hectar has remained generally unaffected or has even declined (Shah, 1981). However, several reasons contribute to this dismal performance of the agricultural sector. First, the funds allocated for production oriented projects were inadequate in relation to the size of the plans and the needs for new investments at the local level. Secondly, the expected amount of local savings, instead of strengthening the government's contribution, was directed to meet consumption needs. And third, the available resources have been misused probably because of poor communication between the farmers and the bureaucrats.

Program Planning Status in Nepal

Nepal has adopted a project-wise approach to conserve and utilize her resources. The concept of the project itself fits into the overall framework of plan, project and program approach to development. So far, the country lacks an overall plan for natural resource conservation and management, although regional level plans have appeared recently. While an indigenous expertise on program planning is developing, search for acquiring quick and effective planning tools are occurring simultaneously.

In recent years uses of quantitative techniques involving the application of electronic devices have also surfaced.[3/] An agricultural credit survey conducted and published by Nepal's state bank (Nepal Rastra Bank) used two approaches, namely a Cobb-Douglas production function and linear programming technique (Nepal Rastra Bank, 1972). The study covered 22 of the 75 districts in Nepal; seven of them were located in the hills. The findings in the Kaski[4/] District revealed that according to the farm plans prepared assuming existing technology, large irrigated farms were found to be operating at the optimal level. In the medium size as well as in small irrigated farms, maize (corn) was found profitable. This study did not include livestock in the analysis.

Paudyal (1980) used linear programming to examine the appropriateness of alternative cropping technologies within a whole farm framework giving emphasis on the linkages involved in the crop-livestock integrated farming system. This study was conducted on one Panchayat[5/] Pumdi Bhumdi part of which falls in the Phewa Tal Watershed. Besides being limited to one Panchayat, thus disregarding regional interaction, this work did not include the minimization of sedimentation as one of the goals. The study also apparently implied that increasing forage supply to improve livestock production was not an important goal for resource management.

[3/] See Paudyal, Dibakar, 1980. The Potential of Cropping System Research Innovations in Crop-Livestock Based Farming Systems in the Hills, Kaski District Nepal.

[4/] Phewa Tal Watershed is in the Kaski District.

[5/] Composition of several villages to form the lowest level of local level governing body (equivalent to a village council).

The results of the two studies were not identical. The agricultural credit survey indicated little probability of increasing net income by reorganizing resource use under existing technology. Paudyal's work concluded that possibilities might exist for increasing net farm income by reallocation of resources under prevailing conditions. The general consensus among decision-makers is that given an approach of completely integrated resource management, opportunities for improvement in the outputs do exist.

Methodological Issues

The objective of a meaningful natural resource management is to enable rural people to enjoy a "better life" in balance with the environment and locally available natural resources. The minimum level for maintaining "better life" can be set at providing sufficient food, minimal housing and some cash.

Natural resource management in the hill region needs to be an integral part of overall rural development of the region. The resource conservation is intimately bound up with rural life in all its facets. Any policy that considers it in isolation is doomed to failure. For example, improvements in agricultural productivity and provision of enough forage from rangeland are necessary conditions to start forest management programs. Cash earning through improved crop and livestock enterprises may dissuade farmers to indiscriminately fell prematured trees to sell fuelwood in the nearby towns. Traditionally entrenched relationships among homestead farms, forest, ranges and other resources, including water resources, needs to be appreciated and evaluated.

There are broadly two approaches to tackle planning and evaluation of such an interdependent system: (i) qualitative approach, and (ii) quantitative/economic approach (Schuler, 1975). Specific information such as what are the trade-offs involved in selecting one management alternative over another, and how well one can meet a given objective with existing resources could not be generated by qualitative approaches. The economic/quantatative approaches are better suited to the needs of studies such as the present one principally due to the following reasons:

1. They are repeatable; hence, one can question and revise them more freely and fully.
2. Alternative strategies are much easier to analyze due to the greater quantification of decisions.
3. Information can be evaluated in a more objective way.
4. As the major objectives of managing natural resources can be termed economic, they could hence be best analyzed via economic/quantitative approaches. The non-economic objectives could also be incorporated through proper selection of the analytical tool.
5. One of the economic/quantitative techniques -- Linear Programming -- is especially helpful in delineating feasible and nonfeasible goals from a physical constraint point of view.
6. Lastly, the multilevel approach to modeling and optimization could be utilized to improve decision making processes.

The Linear Programming (LP) model as an optimizing approach has been applied quite frequently to resource management decision making.

Its application in agriculture is as old as its inception itself. Use of LP in forestry and other natural resource management problems has also been extensive (Field, 1977; Bell, 1977). Determining optimal mixes of products for production at a plywood mill (Bethel and Harrel, 1957); farm wood lot planning (Coutu and Ellertsen, 1960), determining least cost logging transportation systems (Donnelly, 1962); forest regulation problems such as planning and scheduling cutting and planting activities (Curtis, 1962; Loucks, 1964; Kidd et al., 1966); and multiple use resource management (Navon, 1971; Putman et al., 1971; House, 1971; Dyrland, 1973), are a few cases. Bartlett (1974) used LP to carry out budget allocation in managing water basin resources. D'Aquino (1974) used LP for selecting an optimal combination of land use activities in order to maximize a desirable outcome or to minimize an undesirable situation. Medina (1980) used LP to determine economically efficient criteria for investments. Dyer and Barlett (1974) used LP to show how scarce natural resources are to be allocated to numerous public demands and wants. Wong (1980) was among the first few people to use LP in multi-level models.

An approach using LP holds several advantages over other approaches (Bartlett, 1981). It's fairly direct and understandable computation does not require an extensive analytical background. An array of computer programs are available to solve linear programming problems. Several disadvantages also exist. The requirement of formulating the so-called "objective function" of LP is often its limiting factor. All objectives or goals of management must be included in the objective function in a single denominator. Basic assumptions for the present LP model are discussed in Chapter II. Notwithstanding the above limiting factors, LP is generally considered as one of the most viable tools in resource management. It is easy to incorporate multiple, interrelated activities and constraints. Further, the provision of post optimal evaluating provisions (e.g., Parametric Programming) enables the appraisal of considered management plans for their stability. For instance, the parametric analysis helps to guarantee obtaining the best solution even if all objectives are known and quantified.

Focus of the Study

The major focus of this study will be on developing an analytical framework from which one can analyze the available data, sketchy though they may be, in light of the management objectives for the explicit purpose of evaluating available management strategies. Determination of the best mixes of goods and services from the entire land resource is the desired result.

Several studies have been carried out in Nepal to recreate the balance between man and resources. In most of the studies, integration of various components giving stress on the important role of the environment is suggested. However, clear management guidelines are still lacking.

The land manager operating in a poor resource-base and ecologically fragile situation usually has several management options. In such a situation, it is not feasible to set an objective based strictly on an economic criterion. Meeting minimal social requirements overshadow the goal of profit maximization. However, it still is a resource allocation problem. Scarce resources (various land use types, budget, labor, compost and credit availability) need to be allotted in a manner which best serves the interest of the society. Proper resource allocation in such an environment requires the knowledge of objectives and their relative importance, people's preferences of goods and services to be produced and the knowledge of the relationship between resources and end products. This study will present an approach which will suggest the appropriateness of prescribing a particular management alternative in a particular area. The prescribed options are 'forced in' to operate within defined environmental parameters. Basically, the study will deal with the question, given the objectives of management, and their constraints, how should one allocate resources to various management activities in order to provide the best mix of goods and services. The study does not make any attempt to prescribe its findings. With the present level of information available, the study only focuses on the problem: how the present status of inadequate production levels can be improved via a well co-ordinated management plan.

Objectives

The objectives of this thesis can be broadly divided into two:

i) Long Range - to create an environment of balanced and complementary land use planning by employing natural resources management on a comprehensive watershed basis.

ii) Immediate - to carry out a comprehensive study of different management alternatives on the basis of whole-system framework to suggest the most appropriate method and area of allocating scarce resources such as land, capital, compost and labor.

Along with these broad objectives the specific objectives are as follows:

a. To describe the concept of 'whole system' resource management and planning methodology to satisfy multiple goals.

b. To argue the application of operation research techniques to analyze the above stated concept and present a case of applying the LP technique to manage resources of Phewa Tal Watershed in Nepal.

c. To present the technique of multi-level planning and its utility in achieving overall resource management goals.

d. To emphasize the need of incorporating environmental factors in the preparation and evaluation of natural resource management plans.

e. Finally, to furnish some guidelines on natural resource management with reference to suitable follow-up studies.

Scope of the Thesis

It is visualized that this piece of work, would be of a preliminary nature. As the information available is not backed up by sound experiment design and systematic execution, recommendation resulting from this study should be taken in that light. Nevertheless, given the extensive studies carried out in the study area, the author believes that the guidelines provided should be able to furnish useful base for extending this type of study. Identification of several management alternatives provides a knowledgeable resource. On top of all, presentation of a new approach in analytizing the complex

CHAPTER II

STUDY APPROACH AND RESEARCH PROCEDURES

Conceptual Framework

A basic foundation of the approach adopted in this study has been based on the premise that forestry, range management, crop and animal husbandry, and water resource management could be integrated in a mutually supportive system ultimately leading to increased agricultural and labor productivity. A major hypothesis is that development can occur within a growth stage of a resource component as well as across growth stages. Hill farmers have poor access to input and output markets. The production systems are noncommercial and possess highly organized interactions of crops with animals, animals with range and forest plants, range and forest land with cultivated land and entire land with environmental systems like water, topography, soils and micro-organisms. Interactions are crucial to achieve production efficiency. The number of crops which can be grown is limtied by soil fertility which itself is a function of the number of animals and amount of litter collected from forest and scrub lands. These and other interactions were illustrated in Figure 2.1.

Because of the poor integration of production systems with market forces it is difficult to alter the basic components of the system, but better management of forest and rangelands and raising of improved crop varieties and animal breeds could improve production. In the area

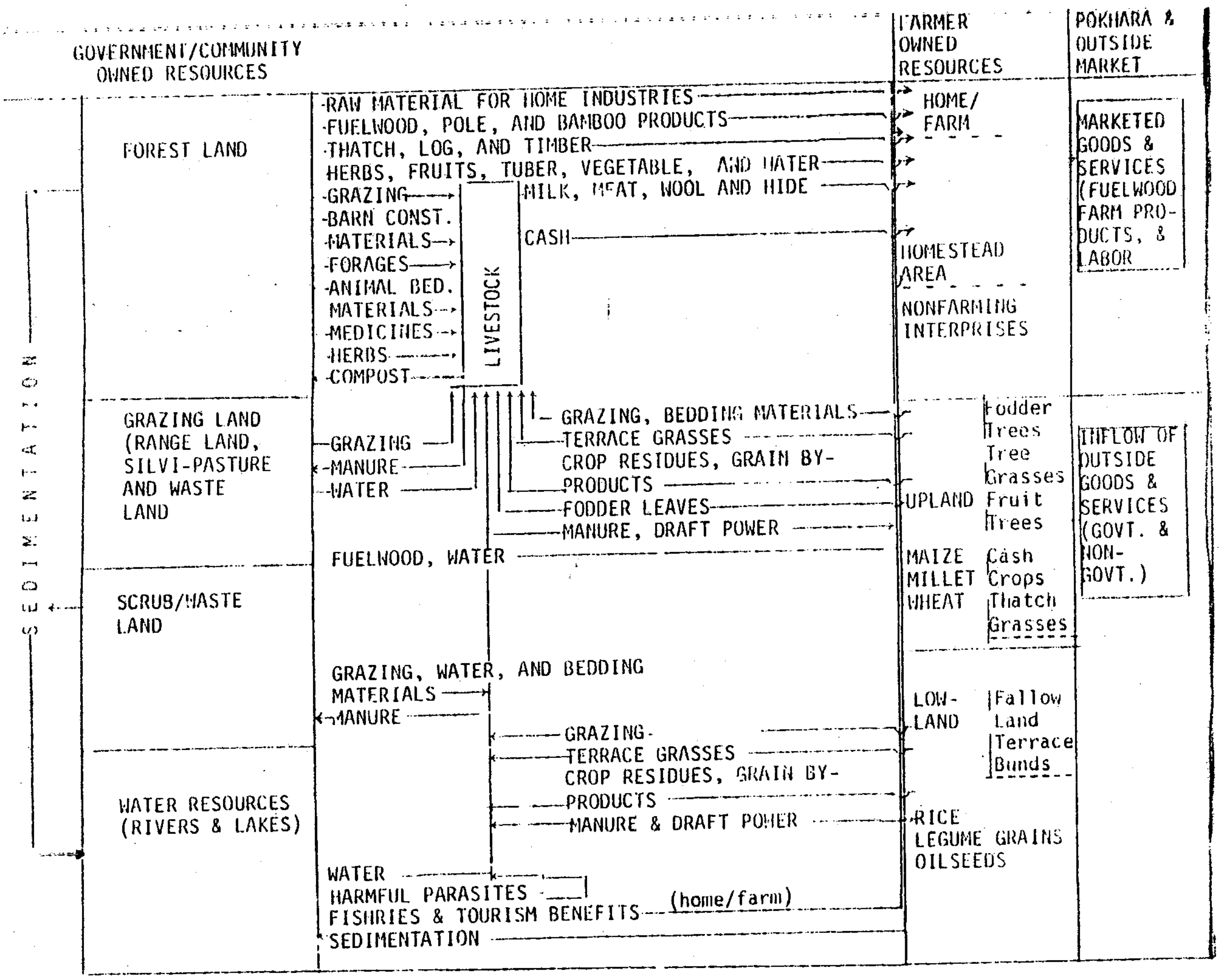

Figure 2.1 A schematic illustration of interactions among elements of natural resources in the hill farming system of Phewa Tal Watershed, Pokhara, Nepal.

where a market is rapidly developing such as in Phewa Tal Watershed, marketing of surplus produce and reinvesting generated capital to achieve limited commercialization would be a natural occurrence. Resource management options in this study are analyzed on these and other concepts.

Selection of General Approach

Several studies have been carried out to recreate the balance between different elements of natural resources and man's activities in Nepal's hill region. In most of the studies, integration of various components giving equal importance to the role of sound environment is heavily emphasized. However, so far there has been only a few studies which have used quantitative approaches to assess the optimal potential of the available resources. In fact, to the best of the knowledge of the author, there has been no such studies in Nepal in the natural resources field.

A careful analysis of the natural resources problems leads us to work with basically four options (USAID, 1980).

a. No action.

b. A single objective approach where a single solution is sought for one local/regional/national problem.

c. A multi-objective approach, where partial solutions are sought for an associated sub-set of local/regional/national problems.

d. A comprehensive integrated approach where simultaneous solutions are sought for all problems existing wthin an area or watershed basin.

Alternative (a), no action, is unacceptable for obvious reasons. Alternative (b) is easily conceived but difficult to execute. Given the existence of various social constraints and almost total use of natural resources in hill areas, it suffers from the danger of overlooking and neglecting vital relationships between the rural population and natural resources on which they depend. It could also tend to concentrate scarce resources on solving single problem(s) of low priority. Alternative (d) is too ambitious. In the face of severe shortage of manpower, infrastructure and enough finance, management of an extensive operation like this is overly difficult. Finally, basic resource data are not available, and there is a great paucity of knowledge needed for constructing and articulating an integrated approach. Alternative (c) is the option which, given the low level of resource endowment, holds some promise although it also requires a fair amount of data. In this study, this option is being evaluated.

Also, a multi-objective approach in resource decision making involves both value judgments and facts. It is important that facts are separated from value judgements in analysis and decision making (Bently and Davis, 1967). Value judgements, though a necessary part of resource decision making should be regarded as the prerogative of the decision maker. The role of the analyst is to present available facts.

This study is mostly concerned with helping the analyst to do a better job by providing the decision maker with as much relevant information as possible.

Thus, the selection of the approach for the present study is based on the need to develop an analytical framework in order to facilitate decision making processes by increasing the range of management options.

Resource Management Strategies

Any strategy aimed at conserving the stock and improving the utilization of natural resources in Phewa Tal Watershed would have to consider the twin goals of meeting the social requirement level of outputs and reduction of sedimentation to a tolerable level. The underlying objective is to achieve economic and social stability through the first goal and ecological stability through the second goal. Ecological stability is crucial to give sustenance to economic stability. Such a strategy may incorporate a few of the following sub-strategies.

Rangeland - Grass Tree System

The combined management of range and forest plants on the same unit of land and at the same time, commonly known as "agro-forestry" is a technique practiced in most countries of the tropical and sub-tropical zones. In general, agro-forestry is defined as:

> A group of land management techniques implying the combination of forest trees with crops, or with domestic animals, or both. The combination may be either simultaneous or staggered in time or in space. The goal is to optimize per unit of production whilst at the same time respecting the principle of sustained yield (Bene et al., 1977).

Unquestionably, agro-forestry techniques belong under "farming systems" which would include farm crops and/or farm animals as a constant feature.

The above concepts can be put into a schematic pattern as shown in Figure 2.2. Through time, the agro-forestry concept has been modified and four major strategies are found in different regions of the world:

i) Agro-silvo-pastoral system - a simultaneous association of three components -- farm crops, forest trees (both fodder and fuelwood trees) and range and pasture plants on a single unit of land.

ii) Silvi-pasture -- a system of practicing controlled grazing on plantation area.

iii) Agri-silviculture -- a combination of forestry and agricultural crops producing either simultaneously or in sequence.

iv) Agri-pasture -- growing of pasture and food crops either on different parcels of the land under the same management system, or growing of grasses on terraces or else growing grasses and legumes as relay cropping, etc.

The selection of one or all of the above approaches to suit the conditions in the Phewa Tal Watershed would have to be based on the following criteria:

- the technique(s) should meet different environmental requirements thus boosting the utilization of solar energy by means of vertical plant stratification.

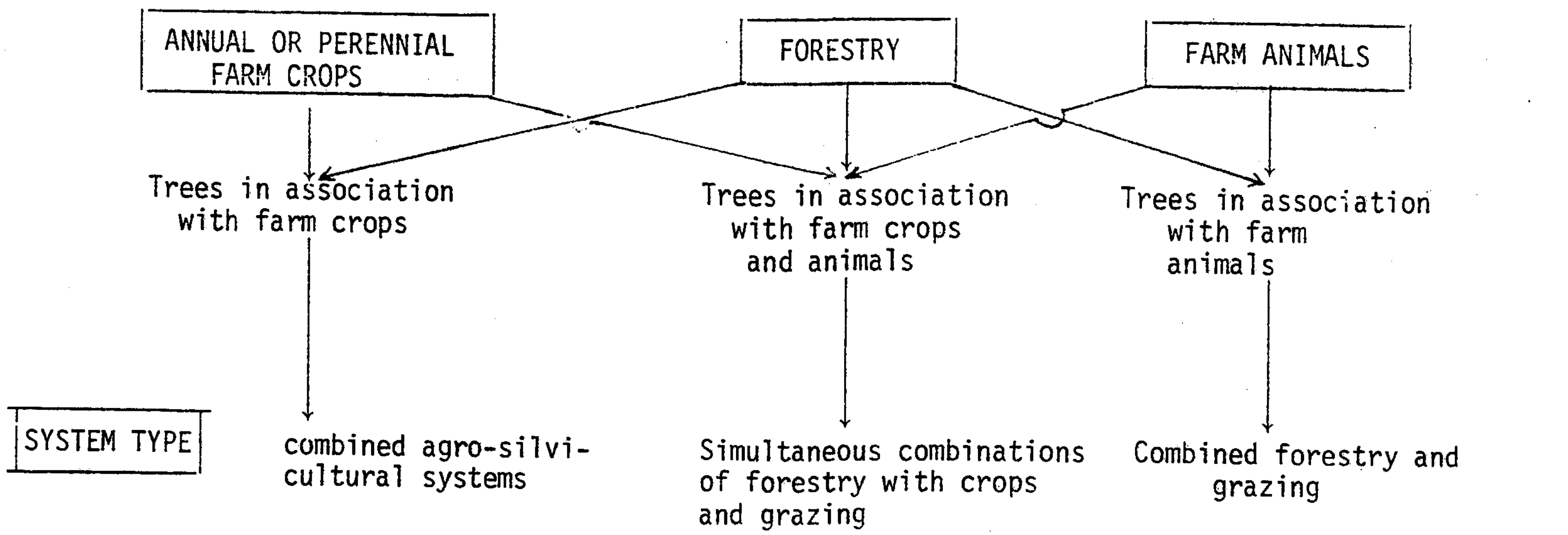

Figure 2.2 Possible combinations of agro-forestry systems by kind of output. (Modified based on Combe and Budowski, 1979).

- to cope with low fertility status of the soils, legumes should be combined with nonlegumes.
- the technique(s) should achieve better bio-geochemical cycling.
- the techniques should make it possible to optimize the efforts of agronomists, stockmen, and foresters to increase production per unit of area while at the same time respecting the principle of sustained yield.
- there should be lower production risks for small farmers.

Forest Land - Multiple Use Forestry

Forests in Nepal have always been managed, though unsystematically, for multiple uses. Future shape of multiple-use forestry in the hills might fit the concept of equal priorities (Hall, 1963). This concept suggests that forest areas can and should produce more than one product at a time (Dana, 1943). Some uses are incompatible, but many are compatible to varying degrees.

Basically, two concepts would guide the strategy to forest land management:

1. The goal of multiple use forestry would not necessary be to achieve maximum yield per hectare of land of any output or for that matter, maximum economic benefit. The emphasis would be on proper balance of uses which takes into account the felt needs of the people and harmony with the environment.
2. No one use has priority over another.

To achieve these goals, the following specific operations would have to be undertaken:

- Separate relatively protected areas from the rest of the forest land and manage them for fuelwood, timber, forage and human food, if any.
- Moderately deforested forests or transitional forests separated for enrichment or gap plantation with fuelwood and fodder trees. Grazing if allowed, would be properly regulated.
- Completely cleared forest land could be first examined for suitability characteristics. Depending upon edaphic and slope factors some version of silvi-pastoral techniques could be adopted.
- Forests with reasonably good stands should be exploited for forest-forage production systems. Suitable grazing approach could be derived based on the experiences of countries like New Zealand, Australia, United States and many African and Latin American countries. The main barriers to building upon the existing informational base for forest-forage systems are largely institutional and are due to the interdisciplinary nature of the subject (Byington and Child, 1981).

Considerable studies have been conducted to indicate the usefulness of forest grazing (McBrayane, 1980; Paterson, 1949; Adams, 1975). Few studies also exist to determine the optimal levels of timber and forage production. Clary et al. (1975) have described the method of obtaining economic optimum level management for joint yield of timber and forage.

Degraded Land Management - Resource Conservation Approach

The Phewa Tal Watershed has significant areas of land of a degraded nature. Scrubland, wasteland and marginal cultivated land could be described under this classification. Currently these lands are under deteriorating situations. Scrubland can be termed as one reaching an ecologically disclimax stage. Cultivated marginal type of land is the result of cut and burn operations (Dils, 1953).

To manage these types of land, land suitability classification needs to be carried out. Slope and soil stability factors would form the major criteria to identify critical land use areas (Copeland, 1965; Fleming, 1978). Another major basis of characterizing the possible land use types could be to set 60% slope as the maximum allowable limit to any type of agriculture (terrace cultivation or grazing). Land beyond 60% slope should have permanent vegetation protection (Copeland, 1965; Green, 1978; Eren, 1971; Sheng, 1973). Therefore the strategy for the management of these land resources would have to be to gradually restore the fertility status through the reduction of sedimentation (current rate is between 17-40 tons/ha). Major features of the proposed management alternatives are described as follows:

1. Scrubland in the vicinity of the settlements due to its being under the direct influence of the people would be managed for the products of immediate needs. Land is cleared off of weedy shrubs and bushes, to carry out two-tier system[1/] of vegetation management. Light grazing may have to be allowed once the vegetations are well established, to accommodate social pressure.

[1/] A term commonly usedin New Zealand which refers to understory grasses and abovestory tree management to produce both forage and timber products.

2. Scrubland located at outlying locations could be managed for either exclusive fodder tree plantation or an intensive tree-grass-legume system. Hand-harvesting of grasses could be practiced.

3. Erosion control on waste and eroded land is thought most difficult technically, but as far as people's cooperation is concerned it would be easily forthcoming. The reason is that it is not usable at the present time. On this type of land establishing massive vegetation cover concentrating upon gullies and land slides could be easily undertaken.

4. At some of the severely eroded sites, combination of engineering and revegetation techniques could be adopted. Construction of check dams followed by grass and transplantation, which is a proven technology in the Phewa Tal Watershed can be pursued further.

5. Yet another strategy to rehabilitate degraded land would be to grow horticultural crops. Provided a follow-up program related to fruit tree management, product marketing and benefit sharing is effectively carried out local people may in time look upon forest and forest products as a farming activity. This would provide valuable incentives to the farmers to plant and care for trees on their own, and thus barren and eroded slopes would be reclaimed. Planting of fruit trees and associated follow-up programs should also be promoted in conjunction with planting grasses. Fruit trees are planted at specific distances from each other so

that the trees have sufficient space for growth and get sufficient sunlight.

Cultivated Land-farming System Approach

A crop-livestock integrated approach generally known as farming system approach is envisaged for cultivated land management. Farming system is the combination of enterprises (cropping patterns, animals, or other ventures under a single farm unit), their resources use (land, labor, time and other inputs) and their interactions (dependency) upon each other (Harwood, 1979). Currently farmers do practice some kind of farming system. The fundamental strategy of providing enough food for the individual family and forage for animals is common to all the farmers in the area. Secondary strategy the farmers usually adopt is to improve their labor efficiency. These strategies are very much alive with the farmers of the Phewa Tal Watershed; however, the pay-offs are constantly declining, possibly due to the following reasons:

1. In many areas, terraces are neglected for years which is resulting in constant erosion problems.
2. Another problem related to soil removal is the rapid decline in soil fertility. This is also due to the deforestation as lesser and lesser amounts of compost is being produced.
3. Traditional cropping technology, though not well known for maintaining stability is not producing enough food grains to keep pace with the rapid population growth.

As reconstructing and building new terraces could be an impractical proposition due to obvious economic reasons, a more practical method of terrace improvement within the reach of an average farmer is building up bunds (terrace walls) or soil banks. On the face of a terrace a thick growth of vegetation could be established; this will slowly collect soil behind it and inhibit the collapse of terrace faces. Another advantage of this method is that these bunds can be utilized for increasing forage production.

To improve the fertility status of the crop land, cropping system approaches can be suggested. Current systems do not include legume pasture in crop rotation. Growing of legumes is an exception rather than a rule. Where terrace systems have failed due to mass movement of land it is found that the land in question is unsuitable for terracing and only a change in land use, and not in terrace design, can be recommended (Green, 1978). This strategy could be adopted in the management of entire marginal lands.

Linear Programming Model

The Setting

Alternative enterprises in any resource system henceforth known as combination of several ecological land units, compete for the manager's limited stock of land, labor, capital, and other commodity inputs. These resources are found to be interdependent if included in the same plan. In consequence, an effective resource planning decision can only be evaluated properly in terms of "whole ecosystem" basis. The whole-system planning problem, which still needs much improvement is to resolve simultaneously:

1) which options to adopt in a particular ecological unit;
2) what method of production to employ in each option; and

3) what amount of resources to allocate to each management option (Anderson et al., 1977).

Whole-system planning problems can be conveniently solved using mathematical programming techniques, of which linear programming (LP) has been the most popular. In the LP terms, the whole eco-system planning problem is to find the optimal values of the variables X_1, $X_2, \ldots, X_j, \ldots, X_n$ where X_j represents the level of the j^{th} management alternatives. The management alternatives are chosen to be representative of all possible enterprises that can be conducted on an ecological unit of all possible ways of undertaking these enterprises.

The choice of activity levels is restricted by a set of linear constraints of the form (from Anderson et al., 1977):

$$\sum_{j=1}^{n} ah_j x_j \quad \{\leqq \; = \; \geqq\} \; b_h \qquad h = 1,2,\ldots, m,$$

where one and only one of the signs $\leqq$, = , or $\geqq$ holds for each constraint, b_h which denotes either an accounting identity or the available stock of the h^{th} resources, and ah_j is the technical coefficients specifying the amount of h^{th} resource required for a unit of product from the j^{th} activity. Competition between activities for limited farm resources as well as the interrelationships between them are reflected by these constraints. Each activity level, X_j , is non-negative, since negative areas of range forest and crops or negative numbers of animal units are impossible.

Optimality is decided in terms of maximization of an objective function subject to associated constraints. The objective function is usually net profit which can be written as:

$$Z = \sum_{j=1}^{n} C_j X_j - F$$

where Z is net profit, C_j is the per unit net revenue of the j^{th} activity and F denotes fixed costs. Since by definition the fixed cost do not vary with the levels of the activities, F can be omitted from the above equation without affecting the choice of an optimal LP solution.

Several assumptions are made in LP solution techniques. First of all, it is assumed that ah_j , bh , c_j are all known constraints -- an assumption implying that all the planning coefficients are known for certain. It is not usually the case, however. Secondly the additivity assumption implies absence of any interaction among the activities of the resources. Thirdly, there is all known assumption of linearity, which states that the objective function be linear. Simiarly, non-negativity of the decision variables, divisibility of activities and resources, finiteness of the activities and resource restrictions, and proportionality of activity levels to resources are other assumptions.

Multi-level Planning

The primary use of LP technique in this model is to optimally allocate the scarce resources to produce a desirable mix of goods, services and uses. However, to show the potential of LP for carrying out more robust planning, its application in multi-level planning process is also discussed. In Nepal the lowest level of planning unit is Panchayat.[2/] There are 3,000 Panchayats in the

[2/] A village, or town level unit for local self government.

whole country. Basically these Panchayats are political units represented by elected members of the people. During the current five year plan (1980-85) Panchayat sectors have been given considerable freedom and responsibility to decide the proejcts which would best meet the felt-needs of the people. Underscoring this shift Nepal's National Planning body syas, "Like the public sector, the Panchayat sector will also formulate its own five-year plan which will be dove-tailed with the national plan as its integral part" (National Planning Commission, 1979). In the Phewa Tal Watershed, there are 7 Panchayats of which only 5 are contained in their entirety. A model of integrating separate plans of 5 Panchayats would have 3-level structure involving Panchayat, watershed and the entire country. In this study LP is used to optimally allocate resources in each Panchayat and based on the outcome of these 6 models, the watershed plan is formulated.

Such a multi-level planning approach has been proposed for the U.S. Forest Service (Wong, 1980). The approach has several distinct advantages over a single-level approach, most notable beinga considerable reduction in the size of higher level models (Bartlett, 1981).

In this study, the Panchayat-level model will allocate land to the various management options and generate a set of management plans expressing the capability of all the land resources within the Panchayat to produce goods, services, and uses. These management plans will be used as input to the watershed level model which in turn would generate a set of watershed level management plans that will allocate budget and target output levels to the Panchayats.

In order to integrate the Phewa Tal Watershed Plan to the National Resource Conservation and Utilization Plan (NRCUP), the capabilities expressed by this model along with similar sets from other watersheds could provide input to the national level model which would generate a set of national management plans one of which could be selected as the national plan. A multi-level model of NRCUP and its planing process is shown in Figure 2.3. The figure links the lower level plans to the upper level ones in an hierarchial fashion. A possibility of linking the watershed level plans similar to the one attempted in this study to the national level plan is also indicated.

Panchayat Versus Watershed Level Models

One of the purposes of using multi-level planning approaches is to avoid the determination of plan decisions at a level higher than where they should be. With respect to the present study, this is to mean that each of the Panchayats in the Phewa Tal Watershed would be made to plan first for its own self sufficiency. A Panchayat would prepare several alternative plans considering the resource potentialities as well as the detailed estimation of local techno-economic conditions as a first step and this would be followed by matching such potentials with developmental possibilities provided by the rest of the economy. Therefore, two types of linear programming models would be developed.

Panchayat Level Linear Programming Model

Chapter IV describes this model in detail. It is a resource allocation model based on the formulation suggested by D'Aquino.

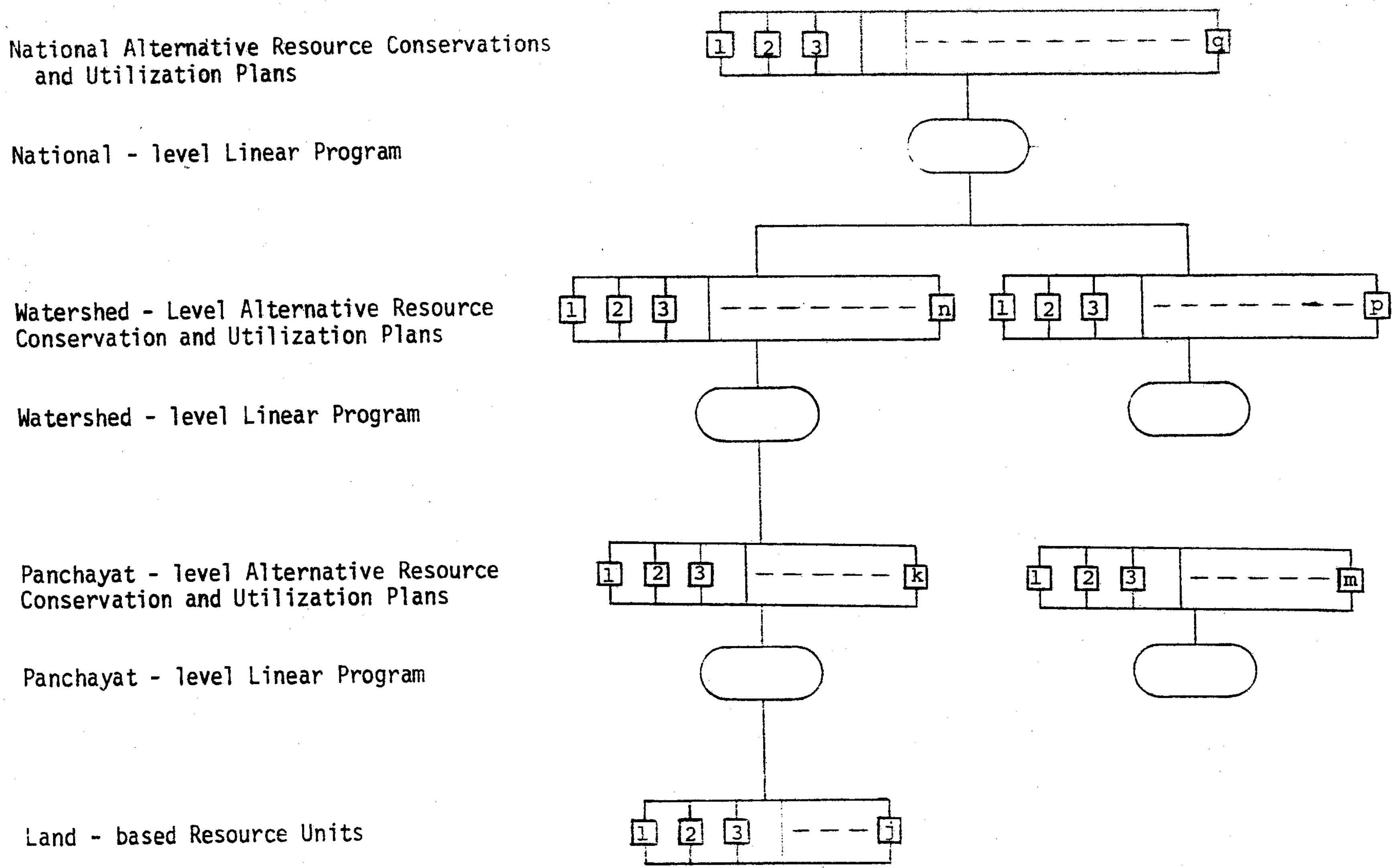

Figure 2.3 Multi-level model of the Resource Conservation and Utilization Planning Process.

(1974). This model was used to generate 6 alternative management plans for each of the 6 Panchayats. Each plan indicated alternative ways of allocating resources in an efficient manner.

Watershed Level Linear Programming Model

The alternative management plans developed for each Panchayat were the decision variables used in the watershed level linear programming model. This multi-level model was applied for 7 different sets of watershed level target values. The purpose was to show that the alternative plans developed reflected the trade-offs of various management activities and objectives. This model is also elaborated in Chapter IV.

CHAPTER III

STUDY AREA DESCRIPTION

Selection of the Area

This study was carried out in the watershed of Phewa Tal which is situated in the Kaski District of mid-west Nepal (Figure 3.1). Several considerations were found favorable to select this watershed as the study area. These were:

1. This watershed is an important test-case for the recently established Department of Soil Conservation and Watershed Management (DSWM). The experiences gained on this site are being contemplated for extrapolation on several other watersheds.
2. It is located in an area where basic infrastructures already exist, and most important of all, this watershed drains water into one of Nepal's most prominent lakes, the Phewa Tal.
3. The government has attributed high priority for the management of this watershed. Sudden collapse of Phewa Dam built only 15 years ago, which supplied vital energy and water needs to the population, provided a glimpse of impending problems in this watershed.
4. Currently, His Majesty's Government of Nepal (HMG/N) with the assistance from the United Nations Developed Program

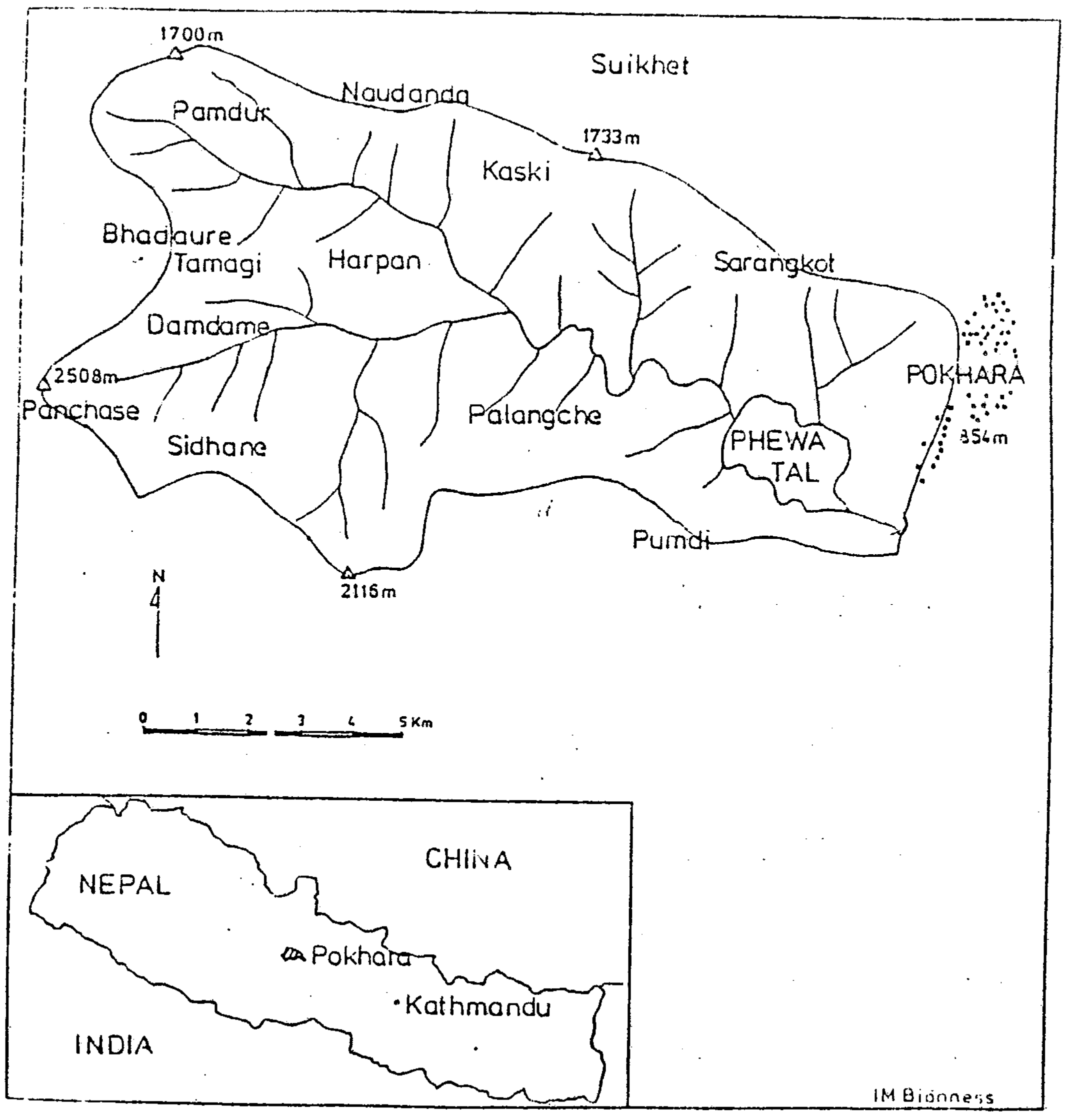

Figure 3.1 Location and orientation map of the Phewa Tal Catchment, Gandaki Zone, Nepal.

(UNDP) had launched several programs to improve both the quality of life and that of environment in the watershed. Successful implementation of the program would depend on the soundness of management activities chosen.

Climate, Topography and Vegetation

The climate of Phewa Tal Watershed is humid sub-tropical to humid temeprate. Mean temperatures in nearby town of Pokhara vary between 12°C in the winter to 25°C in the summer. At higher elevations (Lumle 1,675 m.), temperatures range between 3.5°C - 20°C. During 1971-80 period the average precipitation at Pokhara was 3,943 mm., and at Lumle, the 1976-80 average was 4,589 mm. (Department of Irrigation, Hydrology and Meterology, 1981).* The rainfall pattern is monsoonal, with 85% of the annual precipitation falling during the June through September period (Table 3.1). The analysis of slope categories indicates that 60% of the watershed area has slopes between 20-60%, with an average slope of 40% (Figure 3.2). About 10% of the watershed is flat to rolling (0-10% slope) while 15% of the watershed is very steep (60-100% slope). Forest covers most of the steep slope.

Vegetation, according to the potential forest map (Figure 3.3), indicates variation from sub-tropical rain forest in the lake valley to temperate oak forest on Panchase Peak (2,500 mm). However, due to man's increased activities (intensive agriculture and grazing) approximately only one quarter of the natural forest remains. Between 850 - 1,500 m., a subtropical wet forest consisting of *Schima walichii*

*Within the watershed the annual precipitation varies between 3,500 mm. to 7,500 mm.

Table 3.1. Precipitation records at various location of Phewa Tal Watershed (mm).

Month / Station	Lumle Agri. Centre 1976-1980	Pokhara Airport 1971-1980	Malepatan Hort. Farm 1977-1980	Toripani** Sarangkot 1979	Banpale* 1979	Tamagi** 1979	Panchase*** 1978-1979
Jan.	18.2	17.50	6.3	8.4	7.0	11.3	
Feb.	41.0	34.2	33.4	87.1	NA	83.6	
March	29.0	55.5	63.0	15.7	NA	19.9	
April	119.5	129.5	144.4	140.4	83.5	158.3	
May	289.3	384.9	335.4	316.3	154.9	91.9	
June	746	701.2	563.7	415.8	564.7	492.8	
July	1250.8	885.4	757.2	1125.2	1070.2	1000.9	
August	1233.7	857.2	873.2	1763.3	1285.5	1287.0	
Sept.	624.50	590.0	513.3	573.2	644.5	361.8	
Oct.	178.2	248.7	202.9	398.0	285.0	328.1	
Nov.	38.2	38.7	35.4	12.5	30.0	7.5	
Dec.	21.0	10.0	30.3	63.2	0.0	0.0	
TOTAL	4589.2	3942.8	3558.5	4919.1	4125.1	3843.1	7500 mm

NA - Not Available; * - Data recorded by automatic raingauge; ** - Data recorded by manual raingauge; *** - only estimations available.

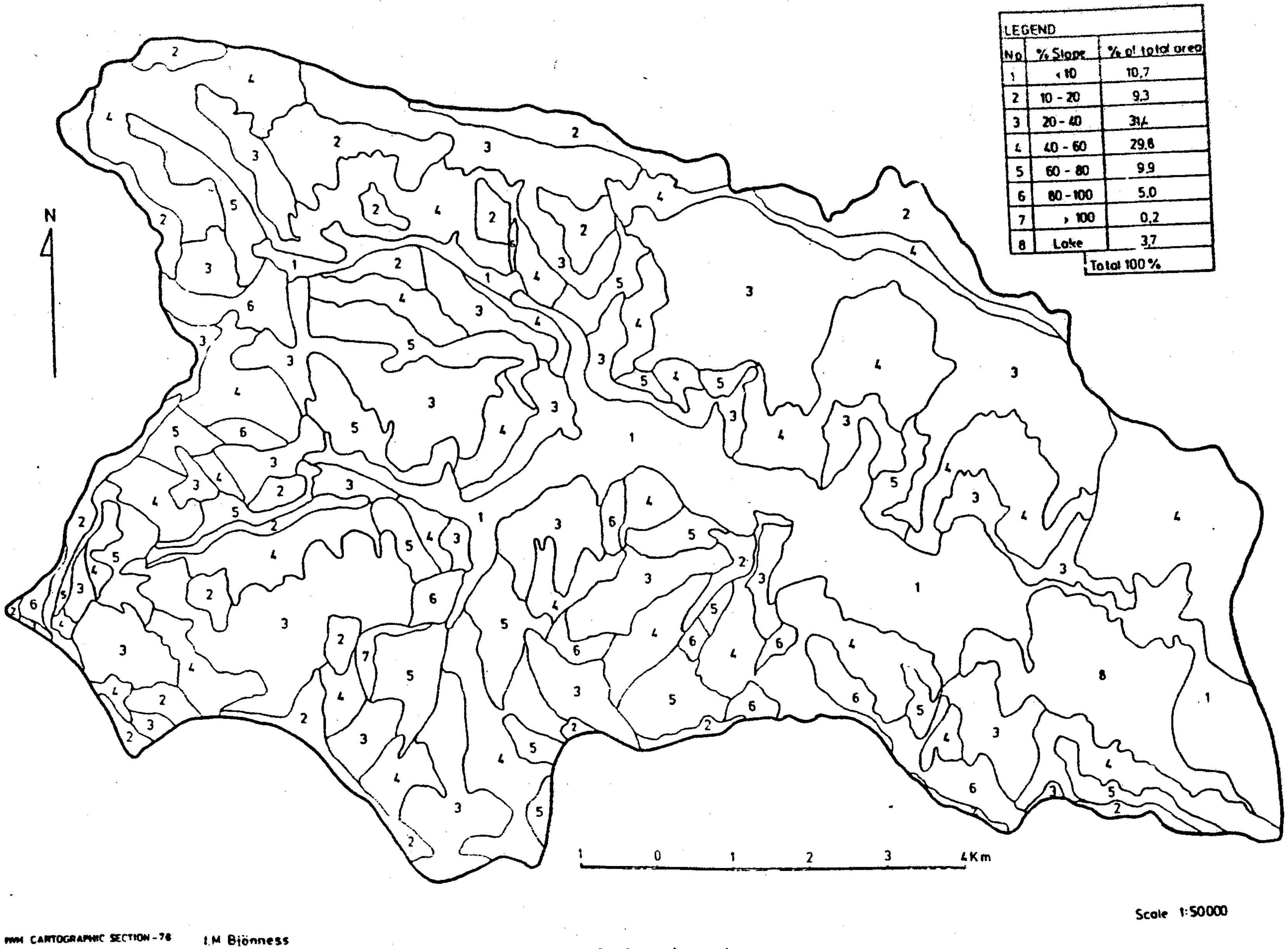

Figure 3.2 Slope categories of the Phewa Tal Catchment.

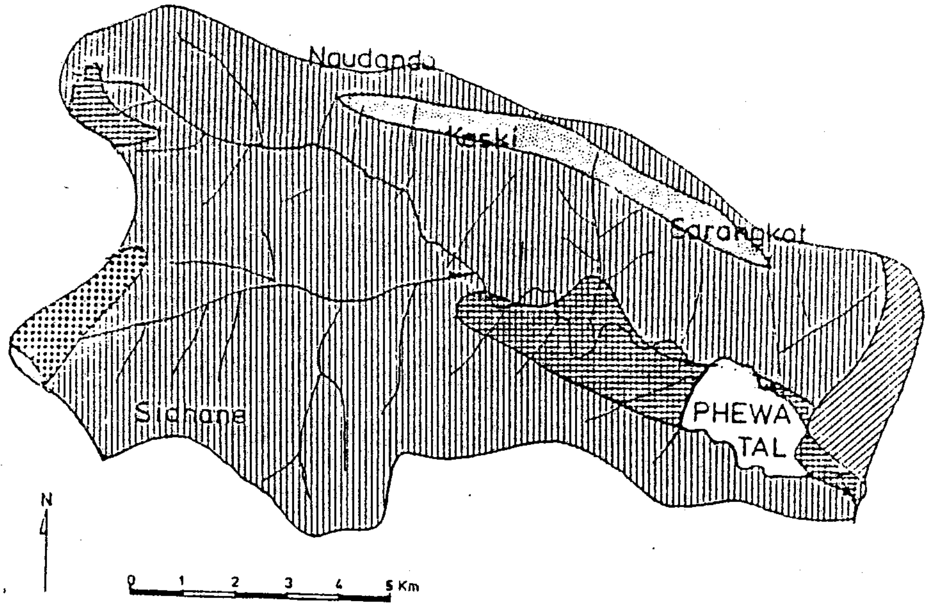

Figure 3.3. Potential forest map of Phewa Tal Catchment (from J. F. Dobremes and C. Jest, 1969 Ecological Map of the Annapurna Dhaulagiri Area, Centre National de la Recherche Scientifique, Paris, France).

and *Castanopsis indica* would predominate had it not been cleared for agriculture. From 1,500 - 2,000 m. the *Schima-Castanopsis* association changes to *Michelia - Laurel - Lithocarpus* mixture indicative of the lower temperate mixed broad-leaf forest (Stainton, 1972). In particular, wet areas and disturbed sites such as gullies and landslides, alder (*Alnus*) may be found. Between 2,000 - 2,500 m. oak forest association (*Quercus lamellosa*) would predominate.

Among grasses, *Cynodon dactylon, Imperata cylindrica, Saccharum spontaneum* and *Themeda* spp., are predominant; legumes are rare. Weeds are common, among them most common are *Eupatorium adenophorum*, braken fern (*Pteridium aquilinum*). Stinging nettle (*Utrica parviflora*) and silver flower (*Anaphalis nubegena*). *Rubiaceae* spp. and *parviflora erubescens* are important shrubs.

Geology and Soils

Schistic and phyllitic rocks predominate the watershed (Figure 3.4). Portions of the watershed with phyllites are considered highly erosive. Soils in the watershed could be strongly acidic (pH 5.1 - 5.5) except on the northern part where slightly acidic to mildly alkaline (pH 6.7 - 7.5) soils occur. Soils contain adequate phosphate but are deficient in organic matter and nitrogen (except where manured). Potash levels are variable ranging from low to medium. Low pH values reduce the availability of the essential nutrients, especially phosphorous and selenium to the plants (Impat, 1981).

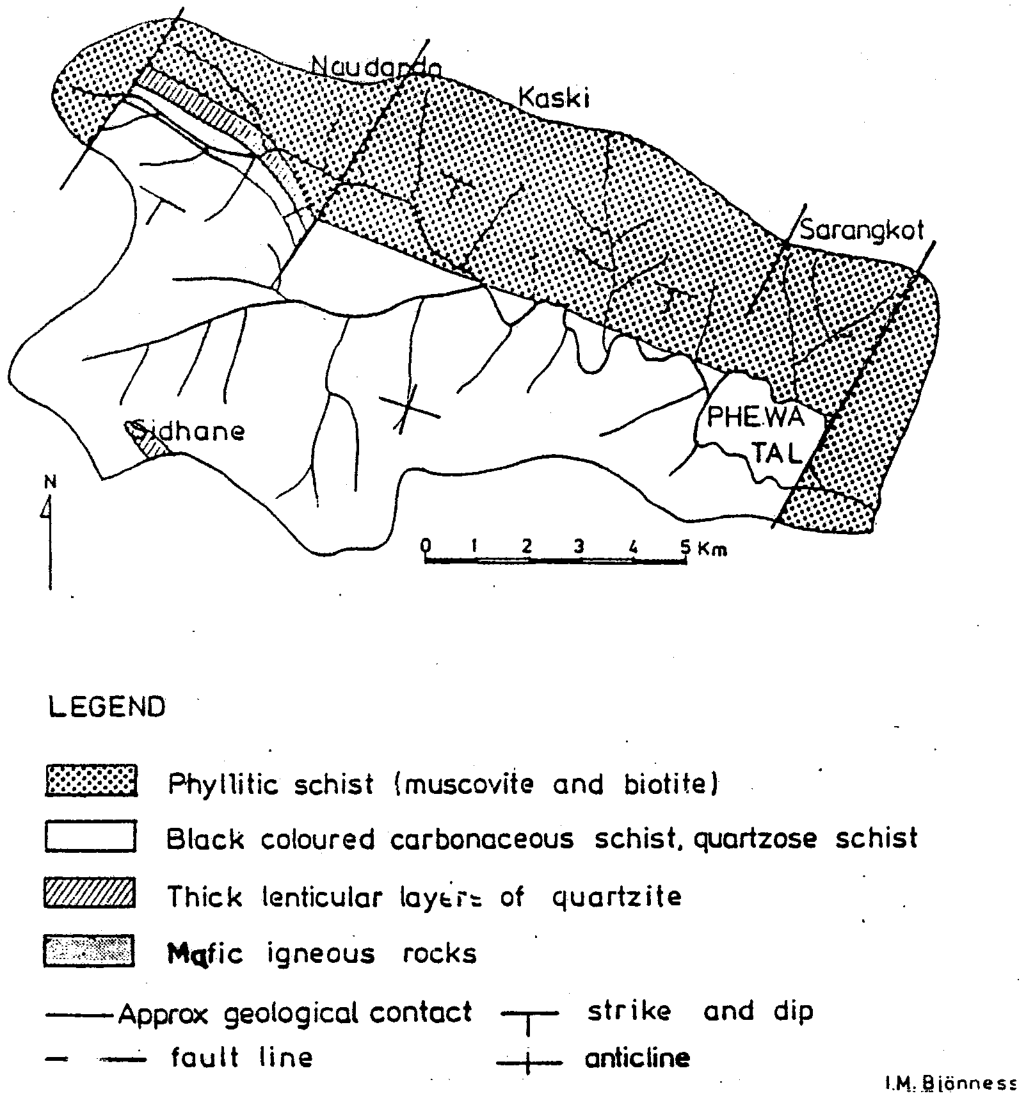

Figure 3.4 Geological map of Phewa Tal Catchment (from Geological map of Nepal by J. M. Remy, 1975).

Socio-Economic Profile and Ecological Consequence

According to the sample of 250 farmers interviewed inthe benchmark extension survey (Scoullar, 1980), average farm size in the watershed is 1.02 ha. with the majority of farms being 0.25 ha. Sixty-one percent of the farms are below the average size. As farm size increases, the proportion of low irrigated land increases. F:fteen percent of the farmers own 38% of the Khetland.1/ The total number of households, obtained by counts on recent aerial photography is 6,306 (Table 3.2). Population from the ward (lowest level of village Panchayat, or village unit) survey totals 33,609. According to the sampled survey (Scoullar, 1980), 50% of the farming population have received no education and only 3.6% have proceeded beyond secondary school.

There is widespread feelings that the general well-being of the people is on the decline. Difficulty in getting enough fodder and fuelwood is expressed invariabily. Crop yields are also thought to be declining. On the south-facing slopes piped drinking water is the most prioritized demand followed by an adequate provision of enough fodder and fuelwood. Better health care for animals is also felt lacking. Gentle slopes are more densely populated. During the last decade, the population grew at 1.95% a year. It is widely premised that increasingly visible ecological problems are largely related to population pressure. Occurrence of large gullies near heavy settlements are the testimony to these effects. Most of the households are unable to find their first preference of tree species for fuelwood.

1/Levelled terrances which can retain water for rice.

Table 3.2 Population and key socio-economic indicators.*

Panchayats	Population	Households (number)	Average for Household	Children (number)	Livestock (number)	Area (ha)	Population (density per ha)	Electricity	Animal units (density per ha)	Village wells Number	taps**
Sarangkot	3,180	671	4.74	1,795	5,448	1,449	3.19	2 houses	6.5	26	2
Kaskikot	4,342	843	5.15	2,905	4,556	1,736	.19	x	3.0	21	0
D. Pokhari	6,273	1,071	5.8	3,349	7,218	1,683	3.64	x	9.0	37	12
Bhadaure	3,856	619	6.23	NA	4,128	2,605	1.16	x	2.0	35	11
Chapakot	3,075	473	6.5	1,295	2,334	2,727	1.14	x	1.7	23	5
Pumdi (3 wards)	1,393	170	8.2	933	1,110	497	3.21	30 houses	2	13	2
Pokhara (6 wards)	13,535	2,459	5.5	5,074	11,225	768	14.6	all wards	12.0	6	4
TOTAL	35,644	6,306	5.65	15,351	36,019	11,465	2.12		3.4	141	36

*Based on Fleming (1978). Modifed by the author to update and/or incorporate additional information.

**Bhadaure and Pokhara have piped water supplies.

The existing type of forest is not as desirable to the villages as the older forests.

Within the past three decades there has been a shift from a forest type which was maintaining a consistent species composition towards a forest type consisting of disturbance-type secondary species. The villagers regard forests as a resource of perennial nature, one which gives output constantly with disregard of how they do it and without requiring any investment.

Resource Base and General Features of the Existing Farming System

People in the Phewa Tal Watershed as elsewhere in Nepal, are largely dependent upon agriculture for their livelihood. How successful they are in extracting natural resources around them indicates their living standard. By natural resources only those resources are referred to which are exploitable through the limited means available to people living in the study area. In most instances the natural resources would include a meager amount of highly fragmented land with inadequate irrigation facilities, some tract of overly grazed barren land to provide small portions of ration to the half a dozen or more animals owned by each household, and access to some acreages of heavily used and dwindling forests to serve as a supply source mainly for fuel-wood, timber and grazing. Water resources are an integral element of the natural resources. In Phewa Tal, the existence of Lake Phewa is very important. Farmers are meaningfully benefited through the economic and aesthetic returns the lake provides.

Arable land is the most vital component of the natural resources. Every effort is made to strengthen the value of arable land sometimes at the expense of other land types. As far as practicable, farmers strive to protect their land assets from both man-made and natural destructions. Through the practice of managing these resources continuing for ages, a system has developed which is entrenched in the life pattern of the households. Generally speaking a farmer will have a system in which he would grow food crops, plant a few fruits, fodder and fuelwood trees, tend a small kitchen garden and keep a few head of animals for draft, milk or meat. To this system we have given a name called the farming system. Figure 2.1 tried to provide a schematic representation of this system. This illustration depicts the interlocking and interdependence of various natural resource components. It may be difficult to alter the basic components of the system, but the better management of these components, such as range and forest land, pasture and shrubland and the introduction of improved varieties on cultivated land could significantly add to production.

Role of Forest and Rangeland on the Whole Eco-system

The two ecological areas where most of animal feed occurs are forest and rangeland. Forest in Phewa Tal Watershed provides up to 30% of the grazing needs during the summer and fall and up to 50% during the winter and spring. Forests are getting increasingly vulnerable to the unabated hunt for more land by the people, and more feed by animals. Rangeland including the barren land, is used by the animals to draw up to 40% of the grazing during summer and about 20% during winter. The necessity for the inclusion of forest and grazing land in the study of farming system arises because of the complete integration of these resources in the traditional patterns of resource regulation by the communities.

Performance of economic strategies by the farmers within this intricate system of farming is always accompanied by some ecologically unsound practices. Deforestation and erosion in the past were not major problems as the environment could absorb these stresses of a smaller magnitude. As the productivity of land is not increasing but demand for fodder, grass and fuelwood is increasing more and more pressure is exerted on these resources. Each year parts of the forest and rangeland are converted into cultivated land without examining their suitability. A highly prevalent trend in the hilly environment of Nepal is shown in Figure 3.4 along with a suggested course of retrieval.

The course of retrieval is nothing more than an environmentalist's dream as the foreward course is as common as the backward course is rare. The results of these trends have been the frequent occurrences of soil loss and erosion problems causing rampant destruction of valuable farmlands including the low rice land along the floodplains downstream. The task is how to keep the remaining of the forest and rangelands undamaged and also how to improve the deteriorated land under ecologically sound and economically productive uses. And this is to be accomplished on the face of expanding human and animal population and lack of promising alternative resources.

Livestock Population, Type and Feeding Resources

Livestock are an integral part of the farming system. They supply milk, manure, meat, draft power and other minor products. Livestock

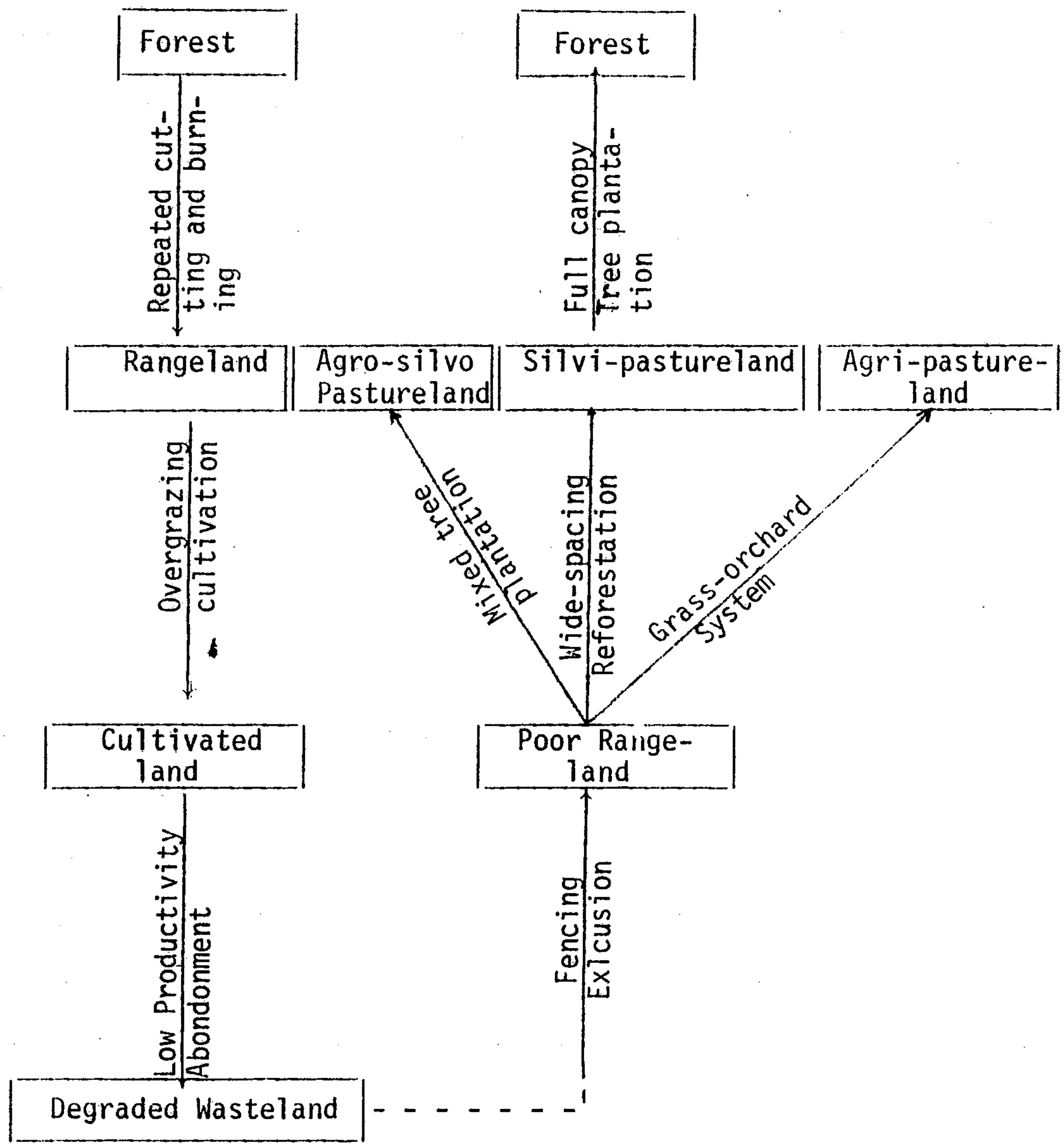

Figure 3.5 Land degradation pattern and suggested retrieval path in the hill region of Nepal.

contributes ¿7% of the income of households in one of the Panchayats -- Pumdi Bhumdi of the watershed (Mathema and Van der Veen, 1980). An average figure of a similar kind for the whole watershed is estimated to be around 30%. The author estimates that there are about 21,000 animal units of different livestock types reared by the people of the watershed. Fifty-six percent of the animals (11,894) are buffalo; 19% (3,970) are cows; 16.5% (3,504) are bullocks; 8% (1,728)are goats and 0.5% (75) are sheep.

The majority of the farmers (66%) rear buffalo, and a very few farmers have sheep. Oxen and goats are reared by the majority of the households. Thirty percent of the households are estimated to own at least one cow (Shah, 1980). On being asked about the reasons for keeping livestock, the common reply is that livestock provides cash income, meat, milk, eggs and animal by-products for household consumption, dung for compost, power for land preparation and a means of savings for possible future cash and/or food needs. The buffalo milk can be readily sold in the nearby urban area of Pokhara.

Shah (1980) carried out a regression analysis between the size of livestock holdings and that of cultivated land holdings; the relationship was positive with a r value of 0.56. In a similar kind of study (Mathema and Van der Veen, 1980), where the number of livestock was related to farm size and family size, the relationship was not highly correlated (r = .40).

Major Environmental Problems

Land distrubance and degradation are roots of major environmental problems in the watershed. Degradation of land and water resources results from tree felling, cultivation, and grazing. These factors are responsible for the watershed's prime problem of soil erosion. Mostly, agricultural practices on terraced land and in valley bottoms do not contribute to erosion (Green, 1978). Rangeland is the most critical erosion category in the watershed because it includes most of the landslide, gully and splash/sheet/reel erosion areas (Fleming, 1978). Rangeland (10% of the area) may contribute over 30% of the total sediment output. The major impact of excessive sedimentation is the rapid damage to the Phewa Lake. Impat (1981) estimates 10 tons per ha per year sediment inflow to the lake with a total of 117,000 tons per year. The above estimation was derived on the basis of the relationship drawn between rainfall at the Pokhara Airport during 1979 and sedimentation. An illustration of this relationship along with those of other locations in the watershed is presented in Figure 3.6.

The natural environment places severe constraints on land use and limits the range of management options (Dunne, 1977; Fleming, 1978). In the watershed itself, decreasing land productivity, depletion of fertile soil resources, and declining availability of fodder and fuelwood pose utmost challenge to the stability of the system.

Resource Management Status, Goals and Problems

The government's stated overall aim of watershed management has been to improve the quality of life and to effect a permanent increase in the productivity of land. Guided by the above objective, Phewa Tal Watershed Development Project has been in operation for some years. However, a detailed management plan for an integrated watershed management has been only recently completed. The plan's strategy is to get resource agencies to cooperate with each other to coordinate their various activities to meet the overall goal of developing a sound watershed. This plan has been scheduled to run between 1980 - 1985. However, the actual implementation is less than one year old. Achieving changes to land use practices so as to reduce soil losses due to erosion to tolerable levels (not more than 10 tons per hectare/year) is the specific goal of the plan (DSWM and IWM, 1980).

However, this plan faces many problems. The plan's success is based on the assumption of achieving complete integration among the participating agencies. However, lack of balanced programs, absence of targets of meeting minimum production levels, and poor evaluation of technological potentials may impede the fulfillment of this vital assumption. It is commonly realized that uncontrolled grazing is the major problem in the area, but the plan poorly tackles this problem.

Resource Appraisal

Land, Crops, Grasses and Trees

Fleming (1978) derived the latest land use figures by land use types and Panchayats based on the imageries shown by aerial photographs. Table 3.3 is a slightly modified version of his information based on the additional information gathered by the author. Figure 3.7 provides the illustrative view of the aforementioned table.

Agricultural land occupies over 50% of the total land area. Three subtypes, viz., i) fully irrigated, ii) partially irrigated,

Table 3.3. Land resources in Phewa Tal Watershed by type of uses of Panchayats. (Unit - ha).

S. No. Land Type	Acreages by Panchayats								
	Sarangkot	Kaskikot	D. Pokhari	Bhadure	Chapakot	Pumdi*	Pokhara*	TOTAL	
1. Range land	235	336	133	391	83	13	19	1210	(10.5)*
2. Forest land	103	111	209	880	1363	219	114	2999	(26.5)
3. Scrub land	181	151	131	378	83	136	13	1072	(9.5)
4. Pasture land	20	48	3	-	-	-	-	71	(0.6)
5. Waste land	13	26	23	3	8	-	10	83	(.7)
6. Fully irri. cultivated land	68	105	75	59	76	3	39	425	(4)
7. Partially irri. cultivated land	345	448	422	275	400	10	59	1959	(17)
8. Rainfed cultivated land	484	511	687	619	714	116	514	3645	(31.8)
TOTAL	1449	1736	1683	2605	2727	497	768	11465	

*Only partially included

**Figures in parenthesis indicate the corresponding percentage.

Source: Integrated Watershed Management, IWM (FAO/UNDP/NEPAL). Phewa Tal Technical Report Number 12. Figures adjusted based on other information gathered by the author.

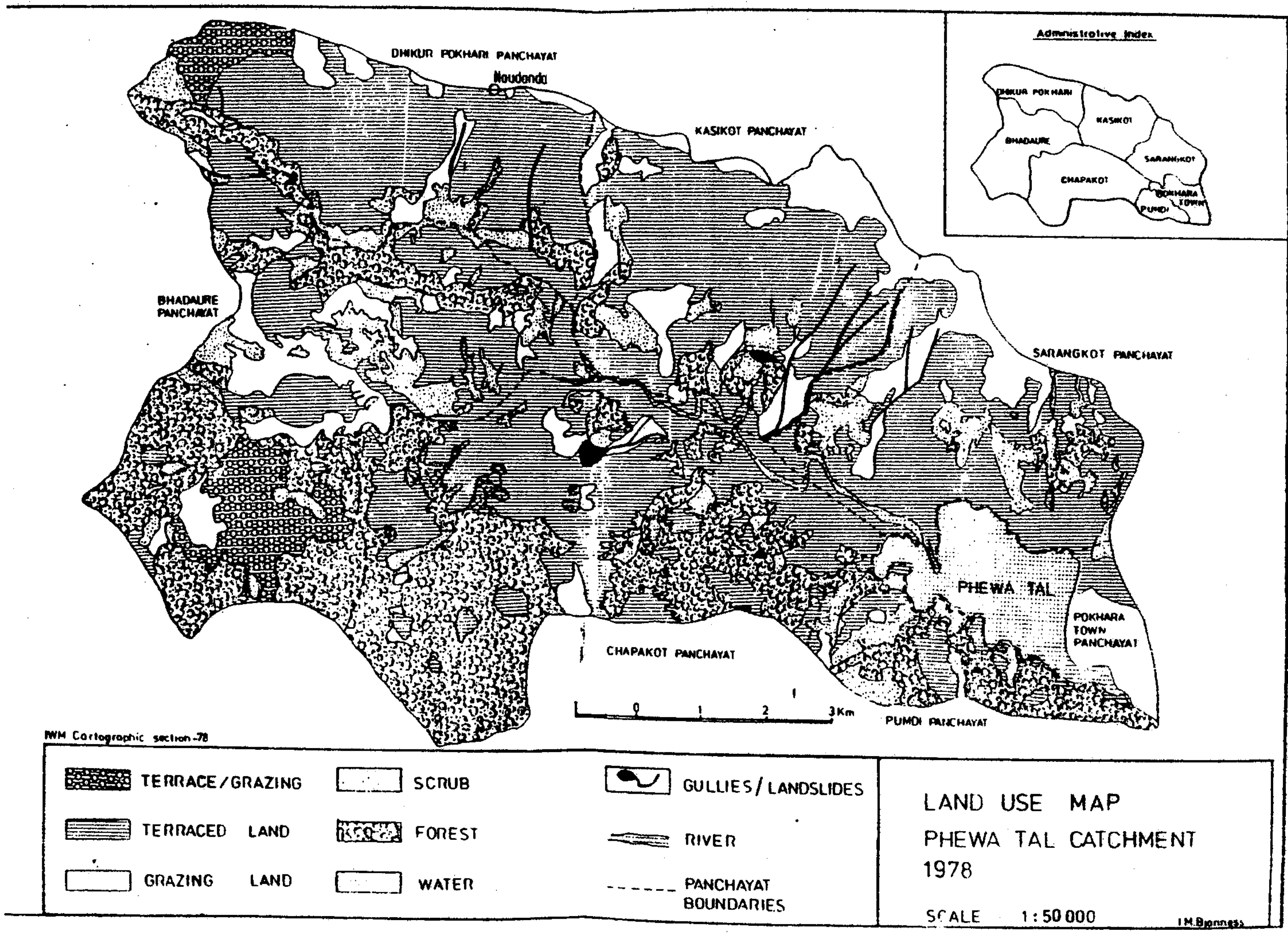

Fig. 3.7 Land Use Classification Map of Phewa Tal Watershed, 1978.

and iii) rainfed upland have been respectively designated as cultivated 'A', cultivated 'B' and cultivated 'C' in the model. The specified acreages under each type are mere estimates based on the author's findings in a household survey in Sarangkot Panchayat. Forest and scrub, together, cover 35.4% of the watershed and only 10.5% is estimated under range. About one half percent of the total area is currently managed under pasture. Each of the above land types show some distinctness in their vegetation characteristics. What follows is a brief description of the characteristics of crops, grasses and trees.

Rice. Rice is the major crop in the fully irrigated valley floors, gentle terraces on lower elevations and some dispersed irrigated pockets in the uplands. The growing season is between April/May through October/November. Two crops of rice are not very common, but below 1,200 m. it is feasible. The average yeild is between 1,780 to 2,000 kgms per hectare, depending upon the type of irrigation facilities. Local varieties predominate. Heavy fertilizer requirement and disease susceptibilitiy impeds the spread of improved varieties. Poor soil management practices and faulty fertilizer application techniques are often associated with poor yield. Some high yielding exotic varieties have been introduced with increasing acceptance among the farmers.

Maize (corn). Maize is an upland rainfed crop. Growing periods are between March/April to August/September. Millet is mixed after two or three months of maize sowing as a relay crop. Maize sown on irrigated lowland is called early maize and is generally used for food, vegetables and forage. Farmers apply heavy doses of organic manures in maize fields. Local varieties are predominantly preferred. However, a few improved varieties are being successfully introduced. The average yield is in the range of 1.1 - 1.5 tons/ha. It is mainly grown on rainfed upland.

Millet. Millet is mainly a companion crop grown side by side with maize plants. One to two month old seedlings are planted in the vacant spaces in the field. The crop is harvested a month or so after maize harvesting. The crop thrives on the heavy dose of compost applied before maize sowing. A few local selections have outyielded the rest of the local varieties. The current yield is 1.0 - 1.4 tons/ha.

Wheat. Wheat is a crop of recent introduction in the Phewa Tal Watershed. Due to its being quickly accepted in the prevailing farming system as well as in the people's dietary habits, it is rapidly spreading as the most popular winter crop. It can be grown both as rainfed and as an irrigated crop. The growing period is between October/November to March/May. Farmers usually apply a small dose of organic and inorganic fertilizer. Production varies according to the amount of irrigation water and fertilizer. The present average is 1.4 tons/ha. It is grown on all three types of land.

Grain legumes. Black gram, soybeans, cow peas and different kinds of beans are commonly grown as legume crops. These are seldom grown as a single crop; black gram is mixed with rice, soybeans is mixed with both rice and maize, peas with wheat and beans with maize. Nitrogen fixing characteristics of these crops may help the main crops. These crops are, however, only supplementary in nature. Production rates are fairly low.

<u>Other crops</u>. Potatoes, mustard and buckwheat are other crops grown. Potatoes are the most common among them. They are also one of the cash earning crops for the farmers. Potatoes are a winter crop in the lower elevations and a summer one in higher elevations. Mustard and buckwheat are upland rainfed winter crops.

<u>Range vegetation</u>. Rangeland in the watershed is probably the most abused but least managed resource. It is excessively grazed and produces high sedimentation endangering the production capacities of other resources such as forests, pasture and cultivated land, not to mention the unrepairable damage done to the lake resources. Besides, the quality of range plants are also vanishing. *Imperata cylindrica*, a low quality feed, *Paspalum* sp. and *Cynodon* sp. are dominant grass species. It is believed that *Imperata*, a perennial grass signals the existence of low fertility status. It is considered as a fire climax vegetation created by repeated burning. Farmers still use fire to induce better regrowth. In Phewa Tal it is estimated to yield dry matter production of 2 - 2.5 tons/ha. In tropical conditions it can yield up to 4 tons/ha (Falvey et al., 1981). *Imperata*, however, is most widely found under dry and open conditions only. *Paspalum distichum*, *Cynodon dactylon* and *Saccharum spontaneum* are other prominent grass species. The average dry matter production for the entire rangeland has been estimated between 1.3 - 1.5 tons/ha. Continuous grazing pressure is expected to depress the productivity gradually. The silvi-pasture land, converted from the degraded rangeland, is producing between 4.5 - 6.0 tons/ha, thus showing the quick reversibility of the rangeland provided some protection is created. The growing period of range plants is between March/April - October/November. Incidently,

the early part of the growing period coincides with the heavy grazing by animals as terrace lands are all occupied by crops and forest grazing is difficult because of high precipitation and leaches. Thus, plants are grazed in the peak growth period which is damaging to the plants. The animals are also distributed unevenly. Southern slopes exhibit animal density of between 5 - 7 Animal Units (AU) per hectare. In contrast, on the north-facing slopes, grazing pressure is moderate (724 AU/ha). Rangeland is conspicuously devoid of leguminous plants. Some recently introduced species have been found to be promising (e.g., *Desmodium* sp.).

Forest resources. As mentioned earlier, forest land is dominated by disturbance-type secondary species. *Daphnephyllum himalayensis* is a dominant species on the elevations above 1,000 m., particularly on the north and north-east facing slopes. *Castanopsis indica* is the next dominant species. *Schima wallichii* is common in the lower elevations particularly on south and south-east facing slopes. *Quercus lanuginosa, Marcaranga postulata, Rhododendron* spp., *Sympolocos ramosissima,* and *Eurya cerasifolia* are other important tree species. Table 3.4 provides the results of dominance in a survey conducted by Levenson (1979) in one of the Panchayats of the watershed.

Scrub land. This type of land is of the transitional type moving from the forest to rangeland. The major plant species are: i) *Castanopsis indica,* ii) *Eurya cerasifolia,* iii) *Colquehounia* iv) *Maesa chisia,* v) *Daphne bholua* and iv) *Dichroa febrifuga.* Scrub land contains both climax and disturbance species. It is estimated that one hectare of scrub land yields about 300 kgms of grass and 1,000 kg of fodder leaves and 2 - 3 m^3 of wood.

Table 3.4 Summary results of dominance survey - Point centered quarter plots, Bhadaure Panchayat.

Plot #	Mean Absolute Density (trees/ha)	All species mean total basal area (cm^2)	Dominant Species	% Dominance
1	1,070	1,982.5	*Daphniphyllum himalayenae*	62.3
2	800	1,777.8	*Symploccos ramosissima*	58.5
3	970	9.501.6	*Castanopsis indica*	85.5
4	1,110	4,085.6	*Schima wallichii*	27.6
5	819	14,406.5	*Schima wallichii*	54.4
6	1,050	5,578.3	*Daphniphyllum himalayensae*	90.4
7	1,250	10,642.0	*Daphniphyllum himalayenae*	84.8
8	714	5,989.2	*Daphniphyllum himalayenae*	86.8
9	532	7,635.2	*Daphniphyllum himalayenae*	79.2
10	415	4,357.0	*Castanopsis indica*	86.6
11	1,300	4,687.3	*Castanopsis indica*	68.4
12	602	8,970.3	*Castanopsis indica*	54.6
13	2,150	2,759.3	*Rhododendron* sp.	47.8
14	1,330	3,157.3	*Daphniphyllum himalayenae*	89.0
15	581	5,187.4	*Daphniphyllum himalayenae*	96.4
16	2,060	2,401.4	*Eurya cerasifolia*	53.1
17	1,830	3,435.8	*Daphniphyllum himalayenae*	89.7
18	1,120	1,608.9	*Daphniphyllum himalayenae*	48.7
19	445	9,476.6	*Castanopsis indica*	40.1
20	758	7,630.0	*Schima wallichii*	41.9
Total	20,906	115,269.8		
Mean	1,045	5,763.5		

Silvi-pasture land. This type of land use is the result of fencing of the open rangeland. In fact, this small area is being managed for multi-objective resource management. Although there has been no reseeding of improved grass and legumes on these protected lands, forage production from the initial year itself has been three to five times higher than on the continuously grazed land. The growth of fodder and fuelwood trees has been rapid. It is felt that quick growing trees such as Alder (*Alnus nepalensis*), *Ficus* spp. and *Litsea polyantha* could start being usable within 6 years of planting. Currently the understory biomass production is in the range of 5 - 6 tons/ha (dry matter).

Other sources of pasture are terrace walls and arable land in fallow. Pandey (1975-76) reported that the terrace walls constitute up to 24% of cultivated land areas in the Trishuli Watershed region, an area similar to the Phewa Tal Watershed. In a successful trial of growing improved grasses on terrace walls, *Setaria anceps* CV 'Nasok', *Chloris guyana* (Rhode grass), *Panicum maximum* (Green Panic) and *Paspallum dilatatum* were recorded to produce dry matter production of 16,450 kgs, 12,500 kgs, 11,638 kgs and 10,442 kgs per hectare, respectively. Two legumes, *Desmodium intortum* (green leaf) and *D. uncinatum* (silver leaf), were also found to be promising. Kalisky (1980) conducted trials on the feasibility of growing winter season forage crops such as *Trifolium* spp. and *Pisum* spp.

Waste land vegetation. Rugged terrain, eroded gullies, and sliding terrace slopes are grouped under this resource type. As this type of land is gradually converted from range and forest lands, the vegetation type is mainly composed of the invader type of species which

CHAPTER IV

MODEL FORMULATION AND APPLICATION

The basic model for this study was formulated in the framework of deterministic linear programming problem. The aim was to achieve an efficient utilization of the resources needed for an integrated natural resources management plan. To extend the use of linear programming technique for multi-level planning this basic model was applied to each of the six Panchayats[1/] of the Phewa Tal Watershed to generate five alternative plans for each Panchayat. Watershed level linear programming model was then constructed to integrate these lower level models into one single model.

Basic Model

The basic linear programming model is comprised of three components, namely, i) a performance index or criterion generally known as an objective function which is optimized; ii) a range of management alternatives to decide the level of each activity, and iii) a set of restraints, representing the resource limitations and other constraining factors. Each component related with the basic model is discussed separately.

[1/] Although there were seven Panchayats contained wholly or partially within the Watershed, two partially incorporated Panchayats were grouped into one thus making only six Panchayats altogether.

Objective Function

Although the model had several simultaneous objectives such as: the fulfillment of societal requirements of various outputs (e.g., Animal Unit Years,[2/] fuelwood and timber products, food grain calories, and minimum sedimentation), for this study the goal or the objective function was defined in terms of the maximization of gross returns (returns net of variable costs). The gross return net of variable costs is the gross revenue minus variable costs associated with each management alternative.

Management Alternatives

Management alternatives were the activities or prescriptions some of which included several treatments over time. These were different types of output generating operations which also included 'do nothing' alternative. The criteria for devising and selecting these activities were:

i) possibility for quick and easy implementation;

ii) existence of recommended technology within the area;

iii) ability to yield maximum amount of desired products; and

iv) distinct characteristics of each alternative.

In all, there were 47 land management alternatives, and 33 product types, thus making 80 total decision variables in the model (Appendix A). This was true for all the five Panchayat level models. Major products considered were animal forage in AUY's, fuelwood and timber

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[2/] An AUY for the purpose of this thesis is defined as the amount of total digestive nutrients (TDN) required to feed a female cow for one year.

products in cubic meters, food grains, grain legumes, and potato in mega calories, sediments in metric tons, milk in kilo liters and meat, wool, and compost in metric tons.

Constraints

Constraints were used for two purposes. Meeting the minimum demand for desired outputs or limiting the production of undesired outputs was one use and forcing the model to work within the defined limits of fixed and variable resources was another purpose. Accounting the levels of unforced outputs and resources was also done through the free rows.

To best explain the generalized optimization model by separating its various components, partition notations are presented in Figure 4.1. Subvector (a) represents the maximum amount of fixed resources, subvector (l) denotes lower limit of renewable resource, (e) quantities of user requirements, (B) upper limit of budget available, (W) upper limit of labor on Mondays, (S) maximum amount of cash available, and (O) lower limit of compost production. Similarly subvector (t) indicates the range of management activities, subvector (f), type of users, and (C) links management alternatives to fixed resources. Submatrix (I) lists the prodction rates of renewable resources, submatrix (J) shows utilization rates of renewable resources and submatrix (H) is linking users to their requirements. Subvectors C,m,k, and r represent the user rates of requirements for variable resources namely budget, labor, cash and compost. The rest of the subvectors and submatrices fill up the zero spaces.

t	f		
C	M	$\leq$	a
I	J	$\geq$	l
N	H	$\geq$	e
c	L	$\leq$	B
m	P	$\leq$	w
K	K	$<$	S
r	F	$>$	0
d	g	$=$	Z

where

(a) Subvector of fixed resources
(b) Upper limit of budget available
(c)[3/] Subvector of budget estimates for each X
(d) Subvector of management costs. Part of objective function.
(e) Subvector of quantity of user requirements
(f) Subvector of users (a column vector, transposed)
(F) Null subvectors to complete array.
(g) Subvector of user revenues - part of objective function
(H) Sub-matrix linking users to their requirements
(I) Sub-matrix of production rates of renewable resources
(j) Sub-matrix of utilization rates of renewable resources
(k) Subvector of cash requirements
(K) Null subvector to complete the array
(l) Subvector of lower limit of renewable resources (generally zero)
(m)[4/] Subvector of labor requirements
(N) Null sub-matrix to complete the array
(o) Subvector of lower limit for compost requirement
(P) Null subvector to complete the array
(r) Subvector of quantity of user requirements
(s) Subvector of quantity of credit supply
(t) Subvector of management alternatives (a column vector, transposed)
(w) Sub-vector of number of man days of labor available
(z) Final value of objective function

Figure 4.1 Partition notation of the basic linear programming model.

[3/] (C) Submatrix linking management alternatives to fixed resources.

[4/] (M) Null submatrix to complete the array.

Alternative Plans

The Department of Soil Conservation and Watershed Management (DSCWM) which has the responsibility for managing the country's watersheds has not yet formulated basic guidelines on which to base the potential plans for specific community.

Therefore, for Phewa Tal Watershed, the alternative management plans have been based tentatively on the general preferences and desires often expressed by the local people and the feelings of the government personnel involved therein. These plans are:

Alternative Plan #1.	Program to produce the economic optimal amount of foodgrains, forage AUY's, fuelwood and timber.
Alternative Plan #2.	Program maximizing the production of food calories.
Alternative Plan #3.	Program aimed at maximizing the pro-dunction of fuelwood and timber.
Alternative Plan #4.	Program to minimize budget while maximizing forage AUY's.
Alternative Plan #5.	Program aimed at minimizing sedimentation.

Based on the above guidelines, five alternative management planning models were constructed for each Panchayat.

The five alternative management plans per Panchayat were the decision variables used in the 'whole whatershed' linear programming model. Although the planning period considered was of 15 years, the plans were given only for a typical year.

A schematic presentation of the basic model is illustrated in Figure 4.2. The management alternatives and product types are shown in the columns. Sediment types have also been shown in the columns. Types of constraints have been shown by the rows. Fixed resources (the land types) represents the system constraints. Product requirements and variable resource levels make up the physical constraints. It is to be noted that there are also some free rows whose functions are of an accounting nature. The mathematical representation of the objective function was shown by

$$\text{Max} \sum_{m=48}^{54} \sum_{n=55}^{59} \sum_{0=60} R_{mno} X_{mno} - \sum_{i=1}^{8} \sum_{j=1}^{k} C_{ij} X_{ij}$$

where

R_{mno} = Gross return from one AUY of animal types (m), one mega calorie of foodgrain types (n), and one m^3 of fuelwood and timber (o).

X_{mno} = Total amount of m, n, and o.

C_{ij} = Management cost for one unit of land type i, and decision variable j.

X_{ij} = Amount of land under each i and j

K = Number j in each i (varying between 3 to 12).

Sources of Data for the Panchayat-level Models

A number of studies have been carried out in the Phewa Tal Watershed by both local and foreign experts during the last few years. However, only a few studies were properly designed and appropriately executed. The author also conducted a household level sample survey during the summer of 1981 covering 85 of the estimated 700 households in Sarangkot Village Panchayat. Also carried out by this author was the studies to estimate the annual aboveground biomass on range, scrub

Activities/Constraints	RHS	Range Coll Row	Range Mgt. Alts. per ha	Forest Mgt. Alts. per ha	Scrub Mgt. Alts. per ha	Pasture Mgt. Alts. per ha	Waste-land Mgt. Alts. per ha	Cultivated type 1/ 'A' Mgt. Alts./ ha	Cultivated type 2/ 'B' Mgt Alts./ ha	Cultivated type 3/ 'C' Mgt Alts./ ha	Animal types AUYs	Calorie types M. Cal.	Fuel-wood & timber M^3	Sedi-ment types	Milk kilo liters	Meat types m. ton	Wood Prod.	Com-post type
Land types	L	1-8	1-12 1	13-17 1	18-23 1	24-26 1	27-29 1	30-36 1	37-41	42-47	48-54	55-59	60	61-78	69	70-72	73	74-80
Livestock types	G	9-15	AUYs	AUYs	AUYs	AUYs	AUYs	AUYs	AUYs	AUYs	- AUYs							
Calorie types	G	16-20	-	-	-	-	-	M.Cal.	M.Cal.	M.Cal		-1						
Fuelwood & timber	G	21	ft^r	ft^f	ft^s	ft^b	ft^w				-	-	-1					
Sediment types	E	22-29	r^s	f^s	s^s	p^s	w^s	$\overline{CA}^s$	$\overline{CB}^s$	$\overline{CC}^s$				-1				
Milk	G	30	-	-	-	-	-	-	-	-	m_1-m_4				-1			
Meat types	G	31-33									m_1-m_4					-1		
Wool	G	34									w_1						-1	
Total animal	G	35									1							
Local cattle	L	36									1							
Impd cattle	G	37									1							
Local buffalo	L	38									1							
Impd buffalo	G	39									1							
Local goat	L	40									1							
Impd. goat	G	41									1							
Local sheep	G	42									1							
Total Calories	G	43																
Calorie types	G	44-48										1						
Fuelwood & timber	G	49											1					
Sediment types	G	50-57												1				
Milk	G	58													1			
Meat types	G	59-61														1		
Wool	G	62															1	
Budget	L	63	B^r	B^f	B^s	B^p	B^w	B^{CA}	B^{CB}	B^{CC}								1
Labor	L	64	L^r	L^f	L^s	L^p	L^w	L^{CA}	L^{CB}	L^{CC}								
Credit & Grant (Cash)	L	65	C^r	C^f	C^s	C^p	C^w	C^{CA}	C^{CB}	C^{CC}								
Total Compost	L	66	K^r	-	-	-	-	K^{CA}	K^{CB}	K^{CC}	C^{AT}							
Compost types	L	67-73	-	-	-	-	-	-	-	-	K^{AT}							
Objective function	N	74	$\sum_{m=48}^{54} \sum_{n=55}^{59} \sum_{0=60} R_{mno}X_{mno} - \sum_{i=1}^{8} \sum_{j=1}^{k} C_{ij}X_{ij}$															

1/ Fully irrigated 2/ Partially irrigated 3/ Rainfed upland

Figure 4.2 Schematic representation of basic linear programming model used in the Panchayat level planning, Phewa Tal Watershed.

Where:

AUY - Animal Unit Years

Ft^r - fuelwood and timber from range land

Ft^f - fuelwood and timber from forest land

Ft^s - fuelwood and timber from scrub land

Ft^p - fuelwood and timber from silvi-pasture land

Ft^w - fuelwood and timber from waste land

r^s - sediment from range land

f^s - sediment from forest land

s^s - sediment from scrub land

p^s - sediment from pasture land

W^s - sediment from waste land

CA^s - sediment from cultivated 'A' land

CB^s - sediment from cultivated 'B' land

CC^s - sediment from cultivated 'C' land

m_1 - m_4 - Milk from local and new cattle and buffalo

M_1 - M_4 - Meat from local and new buffalo and goat

W_1 - wool from local sheep

B^r - B^{CC} - Budget estimates for decision variables

L^r - L^{CC} - Labor estimates for decision variables

C^r - C^{AT} - Cash estimates for decision variables

K^r, K^{CA} -- K^{CC} - Compost requirements in range and cultivated land

K^{AT} - compost production from different animal types

Figure 4.2 (continued). Schematic representation of basic linear programming model used in the Panchayat level planning, Phewa Tal Watershed.

and wasteland. Forage productions from forest understory and terrace bunds were also estimated in the field study. Still it is contended that the data used in this study is 'rough' and not refined to the point where one could apply the results (allocation of acres) without careful review. Nevertheless the information gathered can be considered sufficient enough to indicate the potential of LP or some other quantitative/economic methods in carrying out watershed level planning. Information on land use, erosion problems and resource requirements are considered adequate. The specifics leading to the development of this information will be discussed in detail.

Management Practices

A management practice, as it is used here will mean a set of varied operations which can be performed to exploit the full potential of the particular unit of land. Operations are specific to a particular management alternative except on the cultivated lands; most field operations will be of mixed tree-grass types. Of course, some fodder trees and grasses on the terrace walls are visualized. On cultivated land, proven cropping technologies form the core of management practices. In all, 47 management alternatives were identified, 12 for rangeland, 5 for forestland, 6 in scrubland, 3 each in pasture and wasteland, 7 in fully irrigated lowlands, 5 in partically irrigated lowlands, and 6 in rainfed upland.

Fixed Resources

The LP model for this study is essentially a land-based model. Table 3.2 contains the land resource situation in Phewa Tal Watershed by land use types and by Panchayats. Cultivated land occupies half of the total land area followed by forest land.

Management Costs

The costs for 47 management activities used in this study consisted of four major categories. Labor, commodity inputs, credit and operation costs were major cost items. All the costs have been calculated at net present value. The cost of intermediary product types such as AUY types, calorie types and fuelwood and timber are for the most part reflected in the land management costs associated with these products. Only present gross values of the returns were considered (Appendix A).

Labor cost. Labor cost was by far the largest cost component. Both family and hired laborers were included. Hired labor was priced as per the true market value and family labor was priced as according to its opportunity cost or equal to the value of additional consumption needed to undertake the extra work. The opportunity cost of labor is the alternative earnings in other non-agricultural activities. The market wage rates of hired labor day and bullock power pair were respectively, Rs 8[5/] and Rs 10.

Commodity inputs. Seeds, organic manures, chemical fertilizers and chemicals took a significant portion of the budget. Seeds were generally saved by the farmers from previous year's production. Prevailing market price was charged for the seeds, as they could be readily sold. Fertilizer prices in the area did not reflect the true costs incurred in them due to the subsidies involved, but an appropriate conversion factor has been used to arrive at the economic costs. Similar techniques were used for other inputs as well.

[5/] 1 Rs = 0.0738 U.S. $.

Returns on capital. It is estimated that up to 40 percent of the management budget has to come in the form of credit. Government provides subsidized credit to the farming sector. In this model, the opportunity cost of the domestic capital is used. For this purpose the interest rate assumed is 15%. In the model this has been reflected in the form of a cash (credit and grant) constraint.

Fencing, planting, maintenance and depreciation costs. These costs are mainly involved in nonfarming types of activities. Both barbed wire and stone wall fences were considered. Fencing and planting operations are carried out through the use of family labors except where skilled laborers are required. Fixed resources such as animals, machineries, and implements were depreciated at the rate of 10% per annum.

Production Coefficients

A range of outputs were envisaged out of the defined management activities. Wherever possible, outputs of similar purpose were expressed in the same unit. For instance, forage products were expressed in animal unit years (AUYs). The estimation of the rate of AUY production from each management option was based on several sources. Data for the existing rates were based on the studies conducted by Shah (1980), Wormald (1976) and this author (1981). Projected yields are based on the results in adjoining research stations (Lumle Agriculture Centre, Pokhara Horticultural Farm, Cropping System Study Site, Pumdi Bhumdi and Pokhara Livestock Farm). Potential forage and timber production figures were also drawn from the Food and Agriculture Organization (FAO) reports (FAO Forestry Department, 1979). Crop production estimates were based on the work done by this author in the study site and in other areas of the country (APROSC, 1979, 1980).

All projections were made for 15 years to cover the gestation period of fodder, fuelwood and fruit trees based on projects. Fuelwood and timber products was expressed in cubic meters (m^3). Sediment production was expressed in tons per hectare. It was produced from all the management alternatives. As the minimization of sediment was one goal of selecting any management alternative, certain levels were decided for each land type based on the potential sediment production from the system. Laban (1978) had suggested 10-20 tons/ha/year as tolerable soil loss or an upper limit of acceptable soil loss for Nepal. Few land types already produce well below this limit for which limits have been set to maintain or minimize existing production. For others, e.g., range and waste land, only those management alternatives expected to produce annual sedimentation yield of 12 tons/ha or less were selected and optimization among them was attempted. Details about the production coefficients are given in Appendix B.

The model also considered secondary productivities. Milk, meat, and wool were the major type of livestock products considered. Compost was yet another kind of production involving animals, plants and human labor. However, this input did not constrain the model, as it was not feasible to meet all the fertilizer demands through compost. Chemical fertilizer requirements were incorporated in the budget estimation of each alternative. Food grain productions were expressed in their caloric values.

er Rates of Resources

Budget, credit, labor and compost were four resources which were o dictate the selection of management activities. The rates of their uses have been estimated based on the information gathered in the field by this author, as well as from secondary sources (Fleming, 1978; Scoullar, 1980; Van de Putte, 1979 and Shah, 1981). Credit and grant requirements for each management alternative were calculated based on the findings mentioned in Table 4.1. Compost requirements reflected only what could be applied as a supplementary dose to other sources of fertilizer. Labor availability situation was provided in Table 4.2. Labor rates are discussed in Appendix A. (For Summary see Appendix C.) Utilization rates of forage resources by different types of animals were estimated based on live weight and performance using standard feed requirement values (see Appendix C1).

Budget and Finance

Budget was an important constraint in this model. A grant sum of U.S.$ 2.5 million or Rs. 33.875 million were made available by UNDP (DSWM and IWM, 1980). To this HMG/Nepal committed Rs. 8.4688 million more. Now on a typical year in this 5 year period, about Rs. 8.5 million may be available for various projects (Table 4.3). On an average, a household is expected to contribute Rs. 3,000-4,000 per year through off farm activities which would total up to Rs. 11.445 million/year. An equal amount would be provided through credit. This budget of Rs. 30 million per year can be expected to be realized annually. Therefore, an upper limit for the budget requirements was set at Rs. 30 million. Apart from the budgetary constraint, existence of a cash constraint was also visualized. Cash is comprised of credit and grants. An upper level of Rs. 14 million was set for this constraint.

Table 4.1 Credit requirement in a typical hill district of Nepal (Unit-Rs).

Item	Source & Type of Loan				
	Non-Institutional in kind	Institutional in cash	Non-institutional in cash	Others[1/]	Total
Percentage of loan borrowing households	1.42	20.53	1.05	0.40	23.40
Average amount (Rs.) per borrowing households[2/]	428.44	1272.05	524.94	5034.0	7259.43
Average Interest rate	12.05	13.53	15.99	12.0	12.55

[1/] Friends and relatives

[2/] It is assumed that at least 50 percent of the loan is required to carry out farming related activities. Therefore, in Phewa Tal Watershed the credit requirement has been estimated at the rate of Rs. 3,630 per household.

Source: Rapti Baseline Study (APROSC, 1980).

Table 4.2 Maximum number of labor days available per month and type of labor by Panchayats. 1979-80.

Panchayat	Male Labor (L. Days) @ 30/month	Female Labor[1] (L. Days) @ 70/month	Total Labor/month (L. Days)
Sarangkot	20,130	46,970	67,100
Kaskikot	25,2990	59,010	84,300
D. Pokhari	32,130	74,970	107,100
Bhadaure	18,570	43,330	61,900
Chapakot	14,190	33,110	47,300
Pumdi	5,100	11,900	17,000
Pokhara	36,885	86,065	122,950*
TOTAL	152,295	355,355	507,650

[1]Female labor days maximum available per month look high at first because they work on the whole farm framework usually 10 hours a day (2.5 hours in the morning and 7.5 hours in the afternoon), whereas 6 hours work is given equivalent to 1 day; and secondly, because the available labor days for the partially economically active members (i.e., a third of the usual labor day) is also added up in this category (Adamson, 1980).

[2]To calculare annual labor days multiply the given figures by 10.067 as it was assumed that 302 average annual work days per capita was available in the watershed (AOROSC, 1978).

*In the case of Pokhara, only 25% of this amount was assumed to be available to cary out agricultural and forestry activities.

Source: Based on a key informants survey.

Table 4.3 Budget situation for 1981-82 period for the Phewa Tal Watershed.

Total UNDP Grant - $2.5 million[1/] or	Rs. 33.875 million
Total HMG Grant - $.625 million[1/] or	Rs. 8.4688 million
Yearly Allocation (estimated)	Rs. 8.569 million
Staff Salaries and Office Maintenance[1/]	Rs. 1.619 million
Cash Available for Development	Rs. 6.95 million
Mobilization through credit[3/]	Rs. 11.445 million
Farmer's contribution*	Rs. 11.445 million
Total Estimated Budget Available	Rs. 29.25 million

1/Phewa Tal Watershed Development Office, Pokhara, 1982 (1 US $ = Rs. 13.55).

2/Author's estimation.

Production Requirements

As stated above, the management goal of the watershed is to try to achieve maximum possible production requirements for the people. The products are varied. Foodgrain is given top priority followed by animal forage and fuelwood and timber. Certain procedures have been adopted to arrive at the requirement of each product.

Calorie requirements. It was assumed that a typical person's diet consisted of 40% rice, 20% wheat, 20% maize, 10% millet and 10% legumes and potatoes. The caloric value for one kgm (processed)[6] rice was taken to be 3.54 k. calories, for wheat, millet and buckwheat; 3.32 k. cal for maize; 3.49 k. cals, for legume grains; 3.85 k. cals, for potato, 0.82 k. cals (APROSC, 1980). Further, it was assumed that one adult consumption unit (ACU) in a normal day required maximum of 2.5 k. cals and minimum of 2.0 k. cals. As the study area is of hilly type, 0.2 k. cal/ACU/day is further added. The current population of the watershed is about 36,300 which in year 2000 may reach up to 51,000. An average figure for this period is about 38,000 or about 30,000 ACUs. Now at the rate of 2.7 k. cals per day total calorie requirements for the entire year is estimated 29,600 or 30,000 mega calories (Table 4.4).

Animal forage requirements. At present, between 30,000 - 36,000 livestock (21,171 Animal Units) (Table 4.5) are owned by the people of the watershed. Assuming one female cattle equal to 0.75 AU, one male buffalo, 0.95 AU, one female buffalo, 1.05 AU, one young cattle 0.04 AU, one young buffalo, 0.75 AU and one adult sheep/goat 0.20 AU,

[6] The processed turnover ratio for rice is 0.6, for maize, wheat, millet, 0.9, barlety and legumes, 0.8 and potatoes, 0.75. It also includes 18% allowances for seeds, storage losses, wages and livestock feeds.

Table 4.4 Total calorie needs* in Phewa Tal Watershed (units - mega calories (m.cal.)).

Panchayat	Calorie Type**						
	Rice	Wheat	Maize	Milett	Others	Total***	
	1979	1979	1979	1979	1979	1975	1995
Sarangkot	1044	522	522	261	261	2610	3264
Kaskikot	1621	811	811	810	810	4053	5067
D. Pakhari	1789	894	894	895	895	4472	5591
Bhadaure	880	440	440	220	220	2201	2751
Chapakot	908	454	454	227	277	2269	1656
Pumdi	407	203	203	101	102	1017	1272
Pokhara	3949	1075	1075	987	988	9873	13287
Total	10598	5299	5299	2651	2650	26595	32888

*Calorie needs are based on population profile by Bourini, A. K., op. cit., Adult consumption unit following average prescribed by the Nutritional Advisory Committee, India, 1958. Average subsistence - 2.5 k. cals per ACU/day, minimum subsistence = 2.0 k. cal per ACU/ day.

** Calorie types have been defined on the basis of diet pattern of people in the study area.

***The social requirement of calorieshas been taken as the average of these two values, i.e., 29691 or 30000 mega calories.

Table 4.5 Distribution of animal units* by Panchayat in Phewa Tal Watershed area.

Panchayat	Animal Unit Types					
	Buffalo	Cow	Bullock	Goat	Sheep	Total
Sarangkot	2496	738	604	429	54	4321
Kaskikot	1619	169	336	185	-	2309
D. Pokhari	3342	964	1071	514	-	5891
Bhadaure	1856	371	619	174	21	3041
Chapakot	1306	662	426	199	-	2593
Pumdi	456	67	120	20	-	633
Pokhara	819	999	328	207	-	2353
Total**	11894	3970	3504	1728	75	21171
	(56)	(19)	(16.5)	(8)	(0.5)	(100)

[1]Source: Shah, S. G., 1980. Animal Husbandry and Feed Resource System in Phewa Tal Watershed, FAO/UNDP/HMG, Kathmandu, Nepal.

[2]Source: Sample Household Survey by the author in 1981.

[3]Source: Number of previous studies by Integrated Watershed Management (FAO/UNDP/HMG) Kathmandu, Nepal.

* One animal unit is equivalent to one female cattle.
** Figures in the parenthesis indicate percentage.

the total AUs in the watershed have been estimated to be about 19,000. At the rate of 1.083 tons of digestive nutrient (TDN) requirements per year per AU[7/] current requirements of TDN are 20,600 tons or the equivalent of 19,000 animal (consumption) unit years (AUY) (Table 4.6). After 15 years, the requirements may reach up to 22,000 AUYs. Taking the average, the upper limit has been set at 20,000 AUYs. However, as the present supply of TDN is equivalent to only 7,600 AUYs (Table 4.7), this model would not set an upper limit, but using post optimal analysis attempts to produce the maximum possible AUYs.

Fuelwood and timber requirements. Table 4.8 shows the potential of fuelwood and timber production from the entire land resources. A sustained yield of about 60,000 m^3 per year is the expected maximum production value. Table 4.9 indicates the current requirement is about 18,600 tons (33,850 m^3) and it may grow up to 43,000 m^3 by the year 1995. However, these figures are misleading as people from other localities and most important of all, those of Pokhara depend on this resource for their fuelwood requirements. So no level is being set; instead an attempt is made to produce as much of the amount as would not reduce other output levels, particularly animal forage.

Sediment production. Sediment is an undesirable output. Therefore, its production level is being minimized as much as is feasible. Ten to twelve tons/ha are being suggested as a tolerable level of sedimentation in the Nepalese hills. Based on the soil loss values

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[7/]This is an average figure. Based on live weight and performance using Sen (1971) TDN requirements values are: male cattle, 1.031 ton/yr, female cattle, .935 ton/yr, young cattle, .407 ton/yr, male buffalo, 1.035 ton/yr, female buffalo, 1.083 ton/yr, young buffalo, .77 ton/yr, and sheep/goat, .256 ton/yr.

Table 4.6 Annual total digestive nutrient (TDN) requirements by type of animal units by Panchayats.

	TDN by Animal Unit Type (Unit-M. tons)					
	Buffalo	Cow	Bullock	Goat	Sheep	Total*
Sarangkot	2573	552	623	422	56	4170
Kaskikot	1669	126	346	191	-	2332
D. Pokhari	3446	721	1104	530	-	5807
Bhadaure	1914	278	638	179	22	3031
Chapakot	1346	495	439	205	-	2485
Pumdi	470	50	124	21	-	665
Pokhara	844	745	339	217	-	2145
TOTAL	12262	2967	2613	1765	78	20629

Source: Author's derivation based on Shah, G. S., 1980. Animal Husbandry and Feed Resource System in Phewa Tal Watershed, FAO/UNDP/HMG, Kathmandu, Nepal.

*Equivalent amount in Animal Unit Years (AUYs) would be about 19,048. The level of AUYs requirement has been projected to increase by about 1 p.c. per year thus stabilizing at about 22,000 AUYs a year by 1995. The social requirement for AUYs has been by taking the average of these two figures at 20,580.

Table 4.7 Estimated current forage production from different feed resources in Phewa Tal Watershed areas (Unit-AUYs).

	Forage in AUYs by Panchayats							
Land Type	Sarangkot	Kaskikot	D. Pokhari	Bhadaure	Chapakot	Pundi	Pokhara	Total
Range land	143.0	206.0	81.0	24.0	51.0	8.0	12.0	513.0
Forest land	72.0	65.0	41.0	-	-	-		133.0
Scrub land	90.5	75.5	65.5	189.0	41.5	68.0		530.0
Pasture land	72.0	78.0	146.0	616.0	954.0	153.0		2019.0
Waste land	4.0	8.0	7.0	1.0	2.5	-		22.5
Fully irrigated lowland	55.0	85.0	61.0	48.0	62.0	2.5		313.5
Partially irrigated lowland	280.0	363.0	342.0	223.0	324.0	8.0		1540.0
Rainfed upland	392.0	414.0	556.0	501.0	578.0	94.0		2535.0
Total	1063.5	1294.5	1299.5	1602.0	2013.0	333.0		7606.0

Sources: Author based on following information.

1. Shah, S. G. 1980. Animal Husbandry and Feed Resource System in Phewa Tal Watershed, FAO/UNDP/MMG, Kathmandu, Nepal.
2. Rajbhandari, H. B. and Shah, S. G. 1981. Trends and Projections of Livestock Production in the Hills of Nepal, MFA/HMG, A/D/C, Kathmandu, Nepal.
3. Field survey by the author, summer 1981.

Table 4.8 Expected average fuel wood and timber production by the end of 1980 - 1995 period by Panchayats.

Panchayat	Production by land type (unit cub. m. yr^{-1})				
	Forest land 1/	Scrub land 2/	Pasture land 3/	Others 4/	Total 5/
Sarangkot	1648	724	705	968	4045
Kaskikot	1776	604	1008	1022	4410
D. Pokhari	3334	524	399	1274	5641
Bhadaure	14080	1512	1173	1238	8003
Chapakot	21808	332	249	1428	23817
Pumdi	3504	544	39	232	4319
Total	46160	5240	3573	6262	60235

1/ Production rate is 16 m^3 $ha^{-1}yr^{1}$ based on the assumption that the present productivity of the forest land is 10 - 15 m^3 $ha^{-1}yr^{-1}$ for unmanaged and 25 - 30 m^3 $ha^{-1}yr^{-1}$ for managed forest (Wormald, 1976).

2/ Production is mainly fuelwood at 3 $m^3ha^{-1}yr^{-1}$ given the silvi-pastoral management activities are undertaken.

3/ Production rate is assumed at 3 m^3 $ha^{-1}yr^{-1}$ as a result of agro-silvi-pastoral activities.

4/ Production rate of 2 m^3 $ha^{-1}yr^{-1}$ is based on the revegetation activities on the waste land and fodder trees byproduct harvesting on cropland.

5/ Cumulative production rate is 25 m^3 $ha^{-1}yr^{-1}$.

Table 4.9 Fuelwood and timber products requirement.

Panchayat	Population*		Current Demand for fuelwood**	Total Demand tons***	
	1979	2000	kgm/caput	1979	1995
Sarangkot	3576	4471	550	1967.0	2459.0
Kaskikot	5552	6941	549	3051.0	3811.0
D. Pokhari	6126	7659	652	3993.0	4994.0
Bhadaure	3015	3769	686	2070.0	2586.0
Chapakot	3108	3886	652	2024.0	2534.0
Pumdi	1393	1742	638	889.0	1111.0
Pokhara	13525	18202	343	4637.0	6243.0
Total/Av.	26295	51479	513	18631.0	23738.0

*

**Extrapolated from the study carried out by Levenson, Burt. 1979. Phewa Tal Technical Report No. 9. Fuelwood Utilization: A study of the demand and availabile fuelwood resources at six selected villages.

***The minimum level of fuelwood requirement for the watershed has been set at the average of these two figures, i.e., 22588 M. tons or 41000 cub. m. It is also assumed that timber (sawlog and bole timber) requirement would be about 5 percent of total fuelwood requirement or 2052 cub. m. Therefore, the minimum requirement for fuelwood and timber has been set at 43092 cub. m. or 43000 cub. m.

listed on Table 4.11, each management alternative was assigned certain yield rates. Then depending upon the type of land type, certain maximum allowable sediment production levels were assigned as shown in Table 4.10.

Other production. Milk, meat, wool and compost are discussed under this category. No levels are set for the production goal as these depend upon the number of animals and type of animals selected.

Watershed-level LP Model

The watershed level linear programming model did not have production and acreage limits; instead it was defined by output types and their levels, budget, credit and grant* money, labor and compost. As only a typical year (an average year for 15-year plan period) was considered there was one constraint per output item for an alternative plan in a given Panchayat. The constraints for the watershed level model are given in Table 4.12 and the output coefficients for each Panchayat under each alternative plan are listed in Table 4.13. These alternative plans number 30 at the rate of five plans per Panchayat. As mentioned earlier, these plans would form the decision variables for the multi-level model.

Constraints linking the five alternative plans of each Panchayat were also created. The purpose was to force the model to select, for each Panchayat, one alternative plan or a set of fractional plans where fractions sum to value one. X_i was assumed to be a varaible that could take any value between, and including, zero and one where the value one denotes implementation of plan i and zero denotes no selection of plan

*Refers to direct cash contribution by the government on Public Lands (range, forest, scrub, pasture and waste land) in the form of grants.

Table 4.10 Sediment production levels for different land types.

Land Type	Maximum Allowable Sediment Production — M. tons/ha — Total	Per Unit (ha)
Range land	8,500	7.0
Forest Land	17,000	5.7
Scrub Land	13,000	12.0
Silvi-pasture Land	180	2.5
Waste Land	1,200	14.0
Fully irri. Cultivated Land	2,000	4.7
Partially irri. Cultivated Land	17,000	8.7
Rainfed Cultivated Land	42,000	11.5

Source: Author's assumptions.

Table 4.11 Soil erosion values from hillside plots at different locations.

Site Number	Land Use Type	Country	Soil Loss ton/ha	Source
1.	Irrigated Rice Terrace	Nepal*	4.5	Impat** (1981)
2.	Non-irrigated Terrace	Nepal	17.4	Impat (1981)
3.	Forest Land	Nepal	5.2	Impat (1981)
4.	Scrub Land	Nepal	17.5	Impat (1981)
5.	Silvi-pastoral Land	Nepal	1.2	Impat (1981)
6.	Poor Rangeland	Nepal	12.8	Impat (1981)
7.	Eroded Rangeland	Nepal	30.2	Impat (1981)
8.	Grassland	India	10.5	Vasudevaiah et al. (1965)
9.	Tropical Pasture Grass	India	0.5	Vasudevaiah et al. (1965)
10.	*Cynodon* Grass	India	1.05	Battawar and Rao (1969)
11.	Grass (pasture)	India	3.60	United Nations (1951)
12.	Bare Fallow	India	33.5	United Nations (1951)
13.	Maize Field	India	10.50	Battawar and Rao (1969)
14.	Maize Field	Rhodesia	7.50	Hudson and Jackson (1959)
15.	Hill Rice	India	2.23	Battawar and Rao (1969)
16.	Hill Rice	Java	25.0	Nye and Greeland (1960)
17.	Hill Rice	Guinnea	2.45	Nye and Greenland (1960)
18.	Legume Grains	India	12.3	Battawar and Rao (1969)
19.	Cow Peas	India	4.25	Battawar and Rao (1969)
20.	Dry Forest-range	S. California	6.0	Krammes (1960)
21.	Sparse Grassland	Alberta, Canada	17.2	Campbell (1970)
22.	Dry-front-overgrazed Range	Kenya	30.75	United Nations (1951)
23.	Grass-scrub Mix	India	3.7	United Nations (1951)

*Phewa Tal Watershed

**Data collected in 1975.

Table 4.12. Output items and range of watershed level targets used as constraints in the Phewa Tal Watershed linear programming model.

S. No.	Output	Item	Range of Target Level[a] Minimum	Maximum	Units
1.	Animal	Forage	15,550	20,600	AUY's
2.	Fuelwood	& Timber	50,000	60,000	Cub. m.
3.	Total	Calories	30,000	46,000	mega. cal.
4.	Rice	Calories	10,000	12,000	mega. cal.
5.	Maize	Calories	10,000	12,000	mega. cal.
6.	Wheat	Calories	5,000	6,000	mega. cal.
7.	Millet	Calories	5,000	7,000	mega. cal.
8.	Other	Calories	8,000	10,000	mega. cal.
9.	Old	Cattle	4,500	7,500	AUY's
10.	New	Cattle	1,000	1,500	AUY's
11.	Old	Buffalo	4,500	5,500	AUY's
12.	New	Buffalo	1,500	2,000	AUY's
13.	Old	Goat	1,500	2,500	AUY's
14.	New	Goat	500	1,250	AUY's
15.	Old	Sheep	0	100	AUY's
16.	Range	Sediment	7,500	8,500	M. tons
17.	Forest	Sediment	16,000	17,000	M. tons
18.	Scrub	Sediment	12,000	13,000	M. tons
19.	Silvi-pasture	Sediment	150	180	M. tons
20.	Wasteland	Sediment	1,000	1,200	M. tons
21.	Cultivated 'A'1/	Sediment	1,800	2,000	M. tons
22.	Cultivated 'B'2/	Sediment	16,000	17,000	M. tons
23.	Cultivated 'C'3/	Sediment	39,000	42,000	M. tons
24.	Budget		29,000	30,000	Rs. '000
25.	Credit & Grant		10,000	14,000	Rs. '000
26.	Labor		4,000	5,000	1000 man day
27.	Compost		55,000	65,000	tons

[a]Average value for a typical year during 1980 - 1995 period.

1/Fully irrigated; 2/Partially irrigated; 3/Rainfed upland.

Table 4.13 Output coefficient for each Panchayat in the Phewa Tal Watershed by output item and alternative management plan.

Output Item	Alt. I	Alt. II	Alt. III	Alt. IV	Alt. V
			Sarangkot Panchayat		
Animal Forage	2524	2520	2225	2765	2580
Fuelwood & Timber	1836	1837	3235	1545	2306
Total calories	7193	8063	7193	5507	5232
Rice calories	1940	1939	1939	1840	1912
Maize calories	256	1243	256	1187	541
Wheat calories	734	727	734	1232	358
Millet calories	111	1231	111	655	260
Other calories	4153	2923	4153	593	2162
Old cattle	808	756	623	830	774
New cattle	202	202	156	193	187
Old buffalo	856	806	712	691	645
New uffalo	253	454	401	277	258
Old goat	177	176	223	553	516
New goat	76	126	110	221	206
Range sediment	1645	1645	1997	1645	1410
Forest sediment	566	566	567	566	566
Scrub sediment	1991	1991	2081	2172	1991
Silvi-pasture sed.	40	40	50	40	40
Waste sediment	149	149	156	149	150
Cultivated 'A'[1/]	272	272	272	272	272
Cultivated 'B'[2/]	3277	3277	3277	2442	2242
Cultivated 'C'[3/]	5566	5566	5566	5460	5202
Budget	5816	5815	5738	4185	4932
Credit & Grant	3375	2287	2169	1846	2060
Labor	845	702	684	547	611
Compost	12303	12494	11986	9296	10132
			Kaskikot Panchayat		
Animal forage	3218	3182	3062	3857	3192
Fuelwood & Timber	2016	2016	3760	1591	2017
Total calories	8515	9545	8515	6327	7744
Rice calories	2399	2337	2399	1875	2487
Maize calories	308	1658	308	2518	1206
Wheat calories	1072	949	1072	424	1128
Millet calories	104	4	104	1359	579
Other calories	2447	4568	2447	152	2344
Old cattle	1030	955	857	1157	798
New cattle	258	254	214	270	287
Old buffalo	1094	1018	980	964	894
New buffalo	450	573	551	386	383
Old goat	225	223	306	771	575
New goat	97	159	153	309	255
Old sheep	64	0	0	0	0
Range sediment	2352	2352	2856	2352	2352
Forest sediment	610	610	610	650	610
Scrub sediment	1661	1661	1735	1872	1660

[1/]Full irrigated; [2/]Partially irrigated; [3/]Rainfed upland.

Table 4.13 (continued). Output coefficient for each Panchayat in the Phewa Tal Watershed by output item and alternative management plan.

Output Item	Alt. I	Alt. II	Alt. III	Alt. IV	Alt. V
	Kaskikot Panchayat (continued)				
Silvi-pasture Sed.	96	96	120	120	96
Waste sediment	299	299	312	350	299
Cultivated 'A'	472	420	472	472	420
Cultivated 'B'	4256	4256	4256	4256	2912
Cultivated 'C'	5365	5875	5365	5876	5151
Budget	6693	5559	6604	3750	5589
Credit & Grant	3422	2667	2542	1865	2396
Labor	922	820	800	551	724
Compost	14600	14075	13861	8968	13108
	Dhikur Pokhari Panchayat				
Animal forage	2314	2293	2180	2436	2356
Fuelywood & Timber	3532	3532	4390	3054	3532
Total calories	10967	11205	10967	9237	10104
Rice calories	1544	1515	1544	1905	1453
Maize calories	3190	3536	3190	2041	3418
Wheat calories	3047	2958	3047	946	1871
Millet calories	1532	1532	1532	1125	1787
Other calories	1654	1642	1654	3220	1800
Old cattle	740	688	610	731	589
New cattle	185	183	153	170	212
Old buffalo	787	734	698	609	660
New buffalo	324	413	392	244	283
Old goat	162	160	218	487	424
New goat	69	115	109	195	188
Old sheep	46	0	0	0	0
Range sediment	931	931	1130	931	931
Forest sediment	1149	1149	1150	1149	1149
Scrub sediment	1441	1441	1507	1497	1441
Silvi-Pasture Sed.	6	6	7	6	6
Waste sediment	265	265	265	266	365
Cultivated 'A'	338	300	337	358	337
Cultivated 'B'	4009	4009	4009	4116	4009
Cultivated 'C'	7214	7214	7214	7273	6870
Budget	6015	6007	5966	5940	5229
Credit & Grant	3183	2399	2327	2371	2207
Labor	827	727	717	712	658
Compost	15173	14938	14880	13012	12609
	Bhadaure Panchayat				
Animal forage	3925	3920	3658	4177	3682
Fuelwood & Timber	14710	14711	17145	8382	15444
Total calories	7517	9090	7517	6190	7382
Rice calories	1906	1900	1906	1494	1923
Maize calories	-	1601	55	2096	500
Wheat calories	612	580	612	426	514
Millet calories	470	1646	415	1156	0
Other colories	4529	3463	4529	1018	4445

Table 4.13 (continued). Output coefficient for each Panchayat in the Phewa Tal Watershed by output item and alternative management plan.

Output Item	Alt. I	Alt. II	Alt. III	Alt. IV	Alt. V
	Bhadaure Panchayat (continued)				
Old cattle	1256	1176	1024	1253	921
New Cattle	313	314	256	292	331
Old buffalo	1335	1254	1171	1044	1031
New buffalo	549	706	658	418	442
Old goat	275	274	366	835	663
New goat	118	196	183	334	294
Old sheep	79	0	0	0	0
Range sediment	2737	2737	2346	2737	2346
Forest sediment	4840	4840	4840	4840	4840
Scrub sediment	4158	4158	4347	4272	4158
Silvi-pasture Sed.	0	0	0	0	0
Wasteland sediment	34	34	36	113	35
Cultivated 'A'	236	236	236	236	236
Cultivated 'B'	2613	2613	2613	2788	1788
Cultivated 'C'	7118	7118	7118	7476	6476
Budget	7289	7285	7139	4705	7156
Credit & Grant	3793	3144	2944	2224	3105
Labor	1058	958	923	723	931
Compost	14388	14345	13514	10248	13445
	Chapakot Panchayat				
Animal forage	2810	2795	2730	3561	3228
Fuelwood & Timber	22535	22535	23060	16121	22880
Total calories	9440	11285	9440	7532	7567
Rice calories	2449	2433	2449	1871	1561
Maize calories	363	1920	363	2938	3494
Wheat calories	932	843	932	1077	412
Millet calories	178	1772	178	1040	1927
Other calories	5518	4317	5518	606	173
Old cattle	898	838	764	1068	807
new cattle	247	224	191	249	291
Old buffalo	955	894	874	890	904
New buffalo	393	503	491	356	387
Old goat	197	196	273	713	581
New goat	84	140	137	285	258
Old sheep	56	0	0	0	0
Range sediment	581	581	705	581	498
Forest sediment	7496	7496	7456	7496	7496
Scrub sediment	913	913	953	996	830
Silvi-pasture sed.	0	0	0	0	0
Wasteland sediment	92	92	96	96	92
Cultivated 'A'	342	304	342	344	304
Cultivated 'B'	3800	3850	2600	3800	2600
Cultivated 'C'	8211	8211	8211	8310	7140
Budget	8567	8556	8537	5122	4873
Credit & grant	3894	3602	3557	2551	2664
Labor	1111	1050	1044	734	720
Compost	15767	15653	15585	9945	8735

Table 4.13 (continued). Output coefficient for each Panchayat in the Phewa Tal Watershed by output item and alternative management plan.

	Others*				
Output Item	Alt. I	Alt. II	Alt. III	Alt. IV	Alt. V
Animal forage	1568	1469	1621	1564	1624
Fuelwood & Timber	5574	5574	6130	4064	5574
Total Calories	5638	7175	5638	5328	5356
Rice calories	1289	1280	1289	527	395
Maize calories	320	1579	320	3077	3084
Wheat calories	195	145	195	20	68
Millet calories	158	1497	158	1697	1699
Other calories	3676	2674	3676	7	96
Old cattle	502	441	454	469	406
New cattle	125	118	113	109	146
Old buffalo	533	470	519	391	455
New buffalo	220	264	292	156	195
Old goat	110	103	162	313	292
New goat	47	73	81	125	130
Old sheep	31	0	0	0	0
Range sediment	224	224	272	224	224
Forest sediment	1831	1831	1831	1976	1831
Scrub sediment	1639	1639	1713	1746	1639
Silvi-pasture sed.	0	0	0	0	0
Wasteland sediment	115	115	120	115	115
Cultivated 'A'	189	168	189	168	168
Cultivated 'B'	655	655	655	448	448
Cultivated 'C'	7245	7245	7245	6302	6300
Budget	5731	5725	5696	2875	2959
Credit & grant	2756	2271	2215	1504	1580
Labor	708	621	614	371	382
Compost	10662	10599	10592	6123	6016

*Pokhara and Pumdi Bhumdi combined.

i . Then these constraints are of the form:

$$X_1 + X_2 + X_3 + X_4 + X_5 = 1$$

and there is one constraint per Panchayat.

The Model

The formulation of the watershed level linear program as shown in Figure 4.3, details the decision variables and constraint types used in this multi-level model. Let the decision variable designated as X_{km} be an i matrix comprised of the elements X_{ikm} which are the output levels of items, i ; six Panchayats k ; and five alternative management plans; m , per Panchayat. The objective function is the maximization of profit margin defined as the difference between the gross present value of benefits and present worth of costs of all output items (Equation 1). There are four groups of contraints. The first set (Equation 2) insures that the budget, credit and grant, labor and compost amounts are not used at more than the projected level of availability. In Equation 3, the second set of constraints, it was ensured that the watershed level target of output item i is met or exceeded. The third set (Equation 4) ensures that the production of sediments from individual land types do not exceed the desired limit. Finally, the fourth set (Equation 5) of constraints is to show the extent of an alternative management plan m selected on k^{th} Panchayat. This constraint as indicated earlier forces the selection of one alternative plan per forest or a set of partial alternative plans where the fractional proportions sum to the value one. These proportions range between, and including, the value zero and one. X_{ikm} can not be negative.

$$
\underset{27\times6\times5}{X_{ikm}} = \begin{bmatrix} X_{11m} & X_{12m} & X_{16m} \\ X_{21m} & X_{22m} & X_{26m} \\ \vdots & & \\ X_{27.1m} & X_{27.2m} & X_{27.6m} \end{bmatrix}
$$

where x_{imp}: Output level of item i in a typical year on the k^{th} Panchayat under alternative management plan m.

$i = $
1. Animal forage (AUY's)
2. Fuelwood & Timber

   .
   .
   .

27. Compost

$k = $
1. Sarangkot
2. Kaskikot

   .
   .
   .

6. Pumdi Bhumdi and Pakhara combined

$m = $
1. Optimal production of foodgrains, forage and fuelwood
2. Maximum food grains production
3. Maximum fuelwood and timber production
4. Maximum AUY's under minimum budget requirement
5. Minimum sediment production

Figure 4.3 Formulation of Phewa Tal Watershed level linear programming model.

i . Then these constraints are of the form:

$$X_1 + X_2 + X_3 + X_4 + X_5 = 1$$

and there is one constraint per Panchayat.

The Model

The formulation of the watershed level linear program as shown in Figure 4.3, details the decision variables and constraint types used in this multi-level model. Let the decision variable designated as X_{km} be an i matrix comprised of the elements X_{ikm} which are the output levels of items, i ; six Panchayats k ; and five alternative management plans; m , per Panchayat. The objective function is the maximization of profit margin defined as the difference between the gross present value of benefits and present worth of costs of all output items (Equation 1). There are four groups of contraints. The first set (Equation 2) insures that the budget, credit and grant, labor and compost amounts are not used at more than the projected level of availability. In Equation 3, the second set of constraints, it was ensured that the watershed level target of output item i is met or exceeded. The third set (Equation 4) ensures that the production of sediments from individual land types do not exceed the desired limit. Finally, the fourth set (Equation 5) of constraints is to show the extent of an alternative management plan m selected on k^{th} Panchayat. This constraint as indicated earlier forces the selection of one alternative plan per forest or a set of partial alternative plans where the fractional proportions sum to the value one. These proportions range between, and including, the value zero and one. X_{ikm} can not be negative.

$$x_{ipm} \atop {27 \times 6 \times 5} \quad \begin{bmatrix} X_{11m} & X_{12m} & X_{16m} \\ X_{21m} & X_{22m} & X_{26m} \\ \vdots & & \\ X_{27.1m} & X_{27.2m} & X_{27.6m} \end{bmatrix}$$

where x_{imp}: Output level of item i in a typical year on the k^{th} Panchayat under alternative management plan m.

i =
1. Animal forage (AUY's)
2. Fuelwood & Timber
.
.
.
27. Compost

p =
1. Sarangkot
2. Kaskikot
.
.
.
6. Pumdi Bhumdi and Pakhara combined

m =
1. Optimal production of foodgrains, forage and fuelwood
2. Maximum food grains production
3. Maximum fuelwood and timber production
4. Maximum AUY's under minimum budget requirement
5. Minimum sediment production

Figure 4.3 Formulation of Phewa Tal Watershed level linear programming model.

Equation 1. Maximize Gross Profit

$$\sum_{i=1}^{18} \sum_{k=1}^{6} P_i X_{ikm} - \sum_{i=1}^{18} \sum_{k=1}^{6} C_i X_{ikm}$$

where P_i = gross profit of item i in a typical year

C_i = net present value of costs of item i

subject to

Equation 2. $\sum_{k=1}^{6} X_{ikm} \leq$ available average annual budget, credit, labor and compost (i = 24, 25,...,27).

Equation 3. $\sum_{k=1}^{6} X_{ikm} \geq$ watershed level target amount of item i in a typical year

i = 1,2,...,15

Equation 4. $\sum_{k=1}^{6} X_{ikm} \leq$ maximum sedimentation level of sedimentation type i

i = 16,17,...,23

Equation 5. $\sum_{m=1}^{5} X'_{km} = 1$ for k = 1,2,...,6.

where X'_{km}: fractional proportion of alternative management plan m selected on k^{th} Panchayat

Also, $X_{ikm} \geq 0$ for all i,k, and m.

$0 \leq X'_{km} \leq 1$ for all k and m .

Figure 4.3 (continued). Formulation of Phewa Tal Watershed level linear programming model.

The central purpose of creating distinction between watershed level and Panchayat level model is to separate the area of responsibility for these two planning units. Watershed level management unit is concerned with rational allocation of variable resources primarily budget money. Current practice of using subjective judgment in this process suffers from political manipulation and lack of suitable indicators about the economic returns of allocated funds. The watershed's primary activity, as intermediary control organizations, is the gathering and release of information which could be achieved through the summarization of Panchayat plans. The watershed level model then, uses decision variables defined as Panchayat alternative plans to optimally allocate watershed level targets and budget to a set of Panchayat plans.

The difference between single Panchayat level land allocation model and multi level watershed model can also be explained through a description of matrix statistics. The matirx of Panchayat model measured 74 rows and 80 columns even though it considered only minimum possible management alternatives. For six Panchayats considered in this study the matrix size in a single level model would be of 74 rows by 640 columns. In contrast, the multi-level watershed model was composed of only 34 rows of 30 columns.

CHAPTER V

RESULTS AND DISCUSSION

The results of the multi-level model for Phewa Tal Watershed have been directed to generally conform with the goals and priorities established by the Department of Soil Conservation and Watershed Management (DSCWM), the agency responsible for the management of the country's renewable natural resources. The criteria utilized in the analysis were influenced by the recommendations of recently completed 'Management Plan for the Integrated Development of Phewa Watershed' (DSCWM and IWM, 1980). The plan defined two objectives, namely; a) the plan objective, and b) the program objective. While the plan objective was to facilitate decision making for an integrated development of Phewa Tal basin, the program objective was to accomplish "change" in land use practices so as to reduce erosional soil losses to tolerable levels.

Broadly interpreted the existing Phewa Tal Watershed management plan targets the achievement of sound land use practices while meeting the basic product requirements of local people especially from forestry and agriculture, improvement in soil conservation (erosion control) and maximizing rates of production and economic returns (consistent with environmental objectives).

To achieve the above objective the plan defined various activities. As the plan did not prioritize these activities in order of their importance for the purpose of carrying out analysis in this study, the major activities were ranked (Table 5.1) on the basis of local people's preferences. This ranking resulted in the strategy to formulate alternative plans for the multi-level model of Phewa Tal Watershed.

Table 5.1 Prioritized activity list in order of their importance to the Phewa Tal Watershed.

Priority No.	Activity
1	Reduce Pressure on Grassland
2	Reduce Pressue on Forest
3	Improve Farming
4	Increase Off-Farm Income
5	Reduce Effects of Concentration of Waterflow
6	Reduce Other Sources of Sediment
7	Explore and Enforce Land Use Changes

As mentioned earlier, these prioritized activities were the basis to prepare a criterion list containing the ranking of output items (Table 5.2). Each criterion was used to prepare an alternative management plan for the multi-level watershed model. Although the stated strategies generally conform with the current line of actions contemplated in the Phewa Watershed, the prioritized output items appearing in Table 5.2 are based on the author's own judgement.

Table 5.2 Prioritized list of output items for the Phewa Tal Watershed level model's iterative runs.

Priority No.	Output Item
1	Maximization of AUY's.
2	Maximization of fuelwood and timber
3	Maximization of total calories
4	Minimization of sedimentation under 'no constraint' situation
5	Minimization of sedimentation under variable resources constraints
6	Maximization of gross profit margin

Maximization of the objective function subject to constraints satisfying the watershed level targets proved to be infeasible. An attempt to fulfill the total AUY's requirement also resulted in an infeasible solution. It led to premise that the targets or the estimated requirements for various outputs were beyond the feasibility region. Stated alternatively, the system under the given management could not meet the demand placed on it. To better understand trade-offs within the watershed several formulations of the model were run. Each formulation attempted to maximize or minimize a single output or the use of a group of resources.

Initially, gross profit margin was maximized with all constraints as free rows, that is, there was no enforcement of constraint equalities or inequalities in the model. This optimization produced overuse of all the components of variable resources (Table 5.3). Additionally, it produced one of the highest amounts of sediment and was the highest in the production of fuelwood and timber. Production of AUY's was only 75%

of the targeted value and the objective function value was Rs. 29.656 million -- highest of all.

Maximization of AUY's was the criterion for carrying out the second formulation. A maximum production of 18,000 AUY's was achieved. However, the impact on other output items was pronounced. Fuelwood and timber production fell from 56,019 m^3 in the first formulation to 44,413 m^3 in this particular interation. Total calories also decreased from 49,135 mega calories to 42,025 m. cals. Maize and millet productions also increased, and there was a slight increase in sediment production. The use of variable resources was markedly decreased. Budget and compost components were significantly reduced, but the objective function value was also reduced from Rs. 29.656 million to Rs. 21.585 million (Table 5.3).

Next, the maximization of fuelwood was considered. As the minimum levels of AUY's and food grain calories were kept as constraints, the wood production did not reach the level obtained while maximizing gross profit margin. The level of variable resource use was approximately the same as in the gross profit maximization problem but the objective function value was Rs. 1 million less than that of the previous iteration (Table 5.3).

Food grain calorie maximization was the next criterion of formulating the problem. A maximum amount of 51,918 mega calories worth of food grains of different types could be obtained. There was slight increase in sediment production. Budget, credit, labor, and compost levels were slightly higher than in the preceding formulations, however, the value of the objective function came down from Rs. 28.634 million to 27.279 million.

Table 5.3 Output values for the watershed level target amounts (maximization of AUYs, fuelwood and timber and food calories, and minimization of sediment) and corresponding values of gross profit.

		Iterative Runs							
		Maximize					Minimize		
Constraint	Original Watershed Level Targets	Gross Profit Margin (Rs'000)	AUY's	Fuelwood and Timber (m^3)	Total Food Calories (m. cals)	AUY's Fuelwood and Food Cals.	Sediments Without any Constraint (m. tons)	Sediments with variable resource as constraint (m. tons)	Sediments with all operating con-straint (m. tons)
Animal Forage (AUY's)	20,580	15,500	18,000	15,903	15,879	16,300	15,887	16,791	16,936
Fuelwood & Timber (m^3)	60,000	56,019	44,413	53,849	52,585	52,500	62,699	47,167	47,000
Total Calories (m. cals.)	30,000	49,135	42,025	48,423	51,918	51,737	47,659	43,216	43,377
Rice Calories (m. cals.)	13,100	11,543	10,792	11,472	11,441	10,985	11,041	9,593	10,000
Maize Calories (m. cals.)	7,850	4,937	8,478	6,679	8,346	10,543	8,655	12,481	12,212
Wheat Calories (m. cals.)	5,300	6,494	4,320	6,099	6,221	6,152	6,234	4,239	5,500
Millet Calories (m. cals.)	2,650	2,083	4,601	2,147	3,421	6,236	3,572	6,560	6,503
Other Calories (m. cals.)	4,000	21,893	13,834	21,331	22,784	17,878	18,781	9,204	9,162
Old Cattle (AUY)	6,725	4,229	5,437	4,449	4,556	4,673	4,279	4,589	4,691
New Cattle (AUY)	750	1,158	1,298	1,225	1,266	1,293	1,294	1,344	1,318
Old Buffalo (AUY)	9,515	4,814	4,998	4,810	4,934	5,104	4,699	4,585	4,629
New Buffalo (AUY)	2,380	2,569	2,123	2,500	2,634	2,766	2,306	2,004	2,049
Old Goat (AUY)	1,380	1,845	2,883	1,956	1,637	1,564	2,251	2,992	2,976
New Goat (AUY)	350	884	1,182	958	904	899	1,060	1,281	1,271
Old Sheep (AUY)	75	0	60	0	90	8	0	0	8
Range Sediment (M. tons)	8,500	9,297	8,400	8,350	8,390	8,248	7,986	8,312	8,223
Forest Sediment (M. tons)	16,600	16,494	16,532	16,493	16,493	16,492	16,493	16,637	16,637
Scrub Sediment (M. tons)	12,875	12,107	12,365	11,950	11,935	11,937	11,884	11,943	12,222
Silvi-pasture Sediment (M. tons)	180	177	166	160	148	149	148	155	142
Waste Sediment (M. tons)	1,060	984	1,015	975	966	963	965	966	978
Cultivated 'A' Sediment	1,860	1,848	1,870	1,791	1,734	1,710	1,746	1,771	1,756
Cultivated 'B' Sediment	16,200	16,585	17,653	15,874	17,373	15,417	14,704	15,926	15,169
Cultivated 'C' Sediment	42,000	40,077	41,050	40,201	40,588	39,222	39,238	38,171	38,342
Budget (Rs. '000)	30,000	39,697	32,666	39,203	49,846	36,200	36,716	30,000	30,000
Credit & Grants (Rs. '000)	14,000	15,915	14,840	15,960	16,183	15,377	15,408	13,546	13,521
Labor (Man days)	4,230	4,790	4,277	4,757	4,830	4,520	4,553	3,954	3,950
Compost (M. tons)	65,000	80,349	67,258	79,215	80,840	75,403	76,111	63,033	64,094
Objective Function Value (Rs. '000)	-	29,656	21,585	28,634	27,279	23,467	26,544	19,962	19,923

* In all iterations except in gross profit maximization, minimum target values for all the output items was used as constraints. The idea was to assure that the present level of production was maintained in all the cases.

One of the pressing problems faced by the watershed is to meet three vital necessities of local people, namely, animal forage, fuelwood, and food grains. Therefore, in this particular run maximization of these three products was attempted. Only a slight drop in the production of fuelwood and food calories occurred (Table 5.3) while an increase in animal forages of 400 AUY's was achieved. That a higher level of forage production could be maintained without sacrificing much in terms of fuelwood and food grain production can be explained by the complementary relationship of AUY's with fuelwood and food calories. This is due to the multiple uses of land resources suggested in this study (see Chapter II). Sediment production was also less in this option. Although the objective function value was much less (Rs. 23.467 million) than those obtained in preceding cases, this was partially compensated for by the low level of budget and other scarce resources.

Apart from the optimization of desirable output target levels further optimization runs minimized the undesirable production levels. Minimization of soil losses was one of the important management constraints in the model. However, it was to be accomplished only after ensuring that minimum amounts of important output items were produced and levels of scarce resources were maintained within the set limits. To give the decision maker full knowledge of trade-offs, three different formulations were examined.

First, minimization of sediment production was attempted treating the remaining constraints as free rows. The minimum sediment production achieved was 93,164 m. tons. A positive effect was observed in AUY's production possibly due to the enforcement of stall feeding practices resulting in more efficient utilization. Both fuelwood and calorie productions were observed to be reduced (Table 5.3). Budget and cash investment showed some increase. The value of budget and cash investment was Rs. 26.544 million.

To examine the impact of forcing the model to operate within the estimated limits of resources while minimizing sedimentation, the model was reformulated to include the constraints. A large increase in AUY's production (Table 5.3) and relatively larger decrease in other output itmes were observed. Objective function value was the lowest recorded to this point, Rs. 19.962 million. Sediment production was 93,881 m. tons.

The last model formulation attempted to produce maximum amounts of all the outputs within the budgetary and other restraints while simultaneously aiming at the minimization of sedimentation. Forage production could be pushed up to 16,936 AUY's while the fuelwood and foodgrain calories peaked at 47,000 m^3 and 43,377 mega calories respectively. The minimum sediment production achieved was 93,469 m. tons.

Selected Panchayat Plans

Each watershed plan obtained through the multi-level linear programming problem solution is comprised of different combinations of Panchayat alternative plans. Table 5.4 presents the alternative management plans selected for each Panchayat for each iterative formulation discussed, including the maximized gross profit formulation. For all the seven criteria for which the iterative runs were carried out, one or combination of more than one lower (Panchayat) level plans were selected for

Table 5.4 Panchayat alternative management plans selected for the iterative formulations maximizing different output items.

Panchayat Alternative Plan	Max.1/ Gross Profit	Max. AUY's	Max. Fuel-wood & Timber	Max. Total Food Calories	Max. AUY's Forest & Timber & Food Calories	Min.2/ Sediments Without any Constraint	Min. Sediments with Variable Resources Constraint	Min. Sediments with all Operating Con-straint
Sarangkot One								
Sarangkot Two				.349	1.0	.007		
Sarangkot Three	1.0		.313	.651		.598		
Sarangkot Four		.837						1.0
Sarangkot Five		.163	.687			.395	1.0	
Kaskikot One								
Kaskikot Two			.386	1.0	.467			
Kaskikot Three	1.0		.614				.625	
Kaskikot Four		1.0		.313				
Kaskikot Five					.220	1.0	.375	1.0
D. Pokhari One								
D. Pokhari Two			1.0	1.0	1.0	1.0		
D. Pokhari Three	1.0							.514
D. Pokhari Four		1.0						.486
D. Pokhari Five							1.0	
Bhadaure One		1.0						
Bhadaure Two					.399			
Bhadaure Three					.431			.453
Bhadaure Four							.591	.277
Bhadaure Five	1.0		1.0	1.0	.170	1.0	.409	.270
Chapakot One								
Chapakot Two				.657	.637			
Chapakot Three	1.0	.163	1.0	.343		1.0	.044	
Chapakot Four		.837						.223
Chapakot Five					.363		.956	.777
Others One								
Others Two					.190			
Others Three	1.0	1.0	1.0	1.0	.810	.385		
Others Four							1.0	1.0
Others Five						.615		

1/ Maximize 2/ Minimize * Fuelwood and Timber.

each of the six Panchayats. In other words, most of the watershed level plans were composed of fractions of several Panchayat (lower) level plans.

Plan #1 which aimed at producing the economically optimal amount of animal forage, fuelwood and timber, and food calories was least selected by most of the multi-level planning models. As can be seen from Table 5.4 only in the case of maximizing gross profit margin, no splitting of any selecting Panchayat plan occurs. Selection of split alternative in the remaining of the iterations signifies that none of the existing plan adequately describes the Panchayat's capability to produce outputs and a different management plan should be developed. Specifically, it can be argued that due to the existence of conflicting goals and variations in the management approaches between Panchayat plans and watershed level plans, split selection of alternative plans could not be avoided. This problem coud be rectified through consultations between two levels of planning. In fact this 'forced in' communication is one of the required steps in multi-level planning.

To satisfy the objectives of this study only 7 alternatives were developed, but it is foreseen that many more alternate plans would have to be developed not only at the watershed level but also at the levels of subwatersheds and Panchayats, in order to obtain better planning. The model can also be forced to select only one plan per Panchayat through the use of mixed-integer programming capability. However, this will call for higher costs in terms of computer resource use.

Discussion

A discussion will elaborate the nature of the Panchayat level plans selected by different watershed level plans. For clarity the discussion is carried out for each Panchayat.

Sarangkot. All plans were selected with the exception of plan #1. Plan #3 and #5 were most frequently selected. In all of these plans animal forage was underproduced. Even the maximization of AUY's production could support only 64% of the estimated forage demand (Tables 4.13 and 5.4). Fuelwood and timber production was also well below the target levels. Foodgrain production, however, surpassed the projected demand showing that there is significant potential for improving food production. Only plan #5 could meet the lowest limit for sediment production. Unless constrained specifically variable resources were mostly overused.

Kaskikot. The results indicated that Kaskikot Panchayat produced surplus forage by nearly one-third of the estimated requirement. However, it severely lacked in the supply of fuelwood and timber. Food calories were overproduced by the model, but as compost and labor resources were overused actual production may be much less. Plan #5 was most commonly selected.

D. Pokhari. This Panchayat appeared to be in the most imbalanced state with respect to the demand and supply of resources. Most lacking was animal forage. Even under the reallocation of resources, not more than half the demand of AUY's could be met. Only one-third of its fuelwood and timber demand was satisfied. Apparently adequate production of foodgrain calories was possible. Plan #2, maximization of fuelwood occurred most frequently.

Table 5.5 Summary of product requirements and resource constraints by Panchayats in a typical year.

Constraint Item	Panchayats					
	Sarangkot	Koskikot	D. Pokhari	Bhadaure	Chapakot	Others*
Animal Forage (AUY's)	4,321	2,309	5,891	3,041	2,593	2,986
Fuelwood & Timber (m^3)	4,764	7,383	9,675	5,010	4,909	14,248
Total Calories (m. cals.)	3,264	4,067	5,591	2,751	1,656	14,559
Rice Calories (m. cals.)	1,305	2,026	2,236	1,100	1,135	5,445
Maize Calories (m. cals.)	653	1,014	1,118	555	568	1,598
Wheat Calories (m. cals.)	652	1,013	1,118	555	568	1,597
Millet Calories (m. cals.)	326	1,010	1,110	220	275	1,225
Other Caloires (m. cals.)	326	1,018	1,130	230	295	1,244
Old Cattle (AUY's)	1,207	454	1,832	891	979	1,363
New Cattle (AUY's)	134	51	203	99	109	151
Old Buffalo (AUY's)	2,371	1,376	2,841	1,578	1,110	1,082
New Buffalo (AUY's)	374	243	501	278	196	191
Old Goat (AUY's)	429	185	514	74	199	227
New Goat (AUY's)	max	max	max	max	max	max
Old Sheep (AUY's)	54	-	21	-	-	-
Range Sediment (m. tons)	1,410	2,016	798	2,346	498	192
Forest Sediment (m. tons)	618	610	1,149	4,840	7,496	1,831
Scrub Sediment (m. tons)	1,810	1,510	1,310	3,780	830	1,490
Silvi-Pasture Sediment (m. tons)	40	96	6	-	-	-
Wasteland Sediment (m. tons)	150	2,991	264	34	92	115
Cultivated 'A' Sediment (m. tons)[1/]	272	420	300	236	304	168
Cultivated 'B' Sediment (m. tons)[2/]	2,242	2,912	2,743	1,787	2,600	449
Cultivated 'C' Sediment (m. tons)[3/]	4,840	5,110	6,870	6,190	7,140	6,300
Budget (Rs. '000)	4,000	5,025	5,950	4,700	5,125	5,200
Credit & Grant (Rs. '000)	2,336	2,960	3,788	2,147	1,617	1,152
Labor ('000 man-days)	675	849	1,078	623	476	481
Compost (m. tons)	13,000	6,925	17,675	9,125	7,780	8,960

[1/] Fully irrigated; [2/] Partially irrigated; [3/] Rainfed upland. * Combines Pumdi and Pokhara.

Bhadaure. In contrast to preceding Panchayats, Bhadaure Panchayat was found to be oversupplied with necessary products. Depending upon the alternative plans selected, 50-150% surplus fuelwood and up to 100% surplus foodgrain calories could be produced. However, labor and compsot shortages would constrain the full attainment of these potentials. Plan #5 was selected for most of the iterations.

Chapakot. The results for this Panchayat was almost identical to those of Bhadaure Panchayat. It was found to be the richest of all the Panchayats in terms of forest resources. Forage production was nearly in balance with demand, however, some problems with the actual realization of these potentials are foreseen due to the expected shortfalls in grant money, labor supply, and compost production. Maximization of food calories was the most preferred plan.

Others (Part of Pumdi & Pokhara). As expected these regions showed the most severe shortages. However, as these regions are only parts of Panchayats, not completely falling within the watershed, no conclusive remarks can be made. Nevertheless, the results indicate that part of Pokhara is wholly dependent on the watershed particularly with respect to fuelwood and grazing. Therefore, the shortages indicated by the model are thought to be real. It was found (Table 4.12 and Table 5.4) that estimated productions within the boundaries of these regions would fulfill only one-third of fuelwood, timber and foodgrain needs. Plan #5 was most commonly selected.

In the final section of discussion, brief descriptions of management alternatives, most frequently selected in the watershed levels plans, are given. The discussion is given for each land type separately.

Rangeland. Fencing followed by Napier Grass *Pennisetum Purpureum* plantation was the selected activity when the model was unconstrained with respect to variable resources requirements. However, on being constrained by budget and labor resources the preferred option was overstory plantation of fodder and fuelwood trees combined with understory grass management.

Forestland. Commercial management of forest for fuelwood and timber was the optimal management when the resource constraint rows were made of free forms. However, in real world simulation where constraints do exist the selected alternative was understory revegetation by grasses and legumes with harvest regulation of fuelwood and timber.

Scrubland. Agri-Pasture (combination of fruit orchard and improved grasses) was the most appropriate activity on the scrubland. When the sediment constraint was relaxed 'scrub clearing, fencing, and raising of improved pasture to be managed under rotation grazing' came into solution.

Silvi-Pastureland. When AUY's were maximized, 'replacement of existing grasses with improved species of grasses and legumes' was the selected option. An attempt to produce both AUY's and fuelwood and timber brought 'enrichment plantation for dense stocking, phasing out of understory grasses' into solution.

Wasteland. Sediment constraint played a key role in the selection of decision variable for this type of land resources. The most preferred option was fencing, checkdam construction, and plantation of improved grasses and legumes with overstory fodder tree management.

Fully irrigated cultivated land. Two crops of rice (early and main) followed by wheat, grain legumes or winter pasture was the commonly selected technology in this land type. This confirms the belief that rice based rotations are the most stable farming techniques (Paudyal, 1980).

Partially irrigated cultivated land. Rice followed by winter wheat with 50% each of local and improved varieties was found suitable in this land type.

Rainfed Upland. On this type of land, dominant selection of single activity did not prevail. Depending upon the formulations, one of the following three options came into solution. Spring potato followed by summer rice (upland) and winter crop of legumes and/or pasture was selected provided resource constraints did not exist. Under maize/millet calories maximization problem, maize/millet-wheat with at least 30% improved varieties was found optimal. However, when an attempt was made to maximize AUY's the selected option was growing of maize/millet followed by winter legumes and grasses. In some cases, existing practice of growing local varieties of maize/millet-wheat, a 'do nothing' alternative was also selected.

CHAPTER VI

CONCLUSIONS, APPLICATIONS AND LIMITATIONS

Developing an analytical framework for renewable resource management in the hill eco-system of Nepal was the main focus of this study. Taking Phewa Tal Watershed as a case study, it was premised that in an overlapping and interdependent ecological and social subsystems which are not always understood, a manager requires a practical decision model allowing him to synthesize the available information in order to facilitate his understanding and evaluation of the effects of alternative decisions on the various subsystems.

Phewa Tal Watershed is composed of 21 subwatersheds and at least five Panchayats[1/] (village councils). Panchayats, being the basic unit for data collection and the seat of local government, were thought to be suitable for the lowest level of planning. This is in line with the popular demand that calls for the determination of plan decisions at levels where they most matter. Consequently, a multi-level model was developed as an example application of a multi-level approach to the integrated watershed planning process.

Linear programming was selected as the analytical tool. Linear programming models were constructed at two levels, namely the Panchayat and the watershed. Watershed level objectives were achieved through the coordination of Panchayat level models. The Panchayat level models

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[1/] Two additional Panchayats only partially fall within the watershed.

aimed at the identification of an optimum product output and use levels for each resource using the management objectives and constraints provided.

A scenario for this study was set under the basic contentions that: 1) an integrated and complex fashion of natural resource utilization pattern existed in the hills of Nepal, and 2) wide disagreement prevailed to the often held hypothesis (Schultz, 1964) that there are comparatively few significant inefficiencies in allocating the factors of production in traditional production systems (Dillon and Anderson, 1971). It was presumed that there existed a high potential for improving the productivity of these resources using a systematic and scientific management and planning technique.

In light of the above background, the results of the multilevel linear programming provided the following guidelines.

1. Tentatively, there existed a significant possibility for increasing the availability of basic human requirements through reallocation of resources under prevailing conditions.
2. Resources in a subsistence production system may be managed more efficiently if the interactions are considered. Whole-system planning carried out in this study was shown to tackle the interaction consideration effectively.
3. Through the alternation of management practices and effective sharing of resources between Panchayats the supply of animal forage could be more than doubled.
4. Dependency of Pokhara was a critical factor in offsetting the balance between demand and supply of products in the

watershed. The human as well as animal pressure on the watershed can be alleviated only if Pokhara finds an alternate source for fuelwood and forage.

5. The excessive sediment production due to frequent land slides and soil erosion mainly from range, waste and fallow, and rainfed cultivated terrace lands, although partially attributable to natural phenomenon, can to a major extent be controlled. through proper changes in land use practices. Fuelwood and foodgrain productions were inversely related to sediment production, whereas, no relationship could be established between AUY's and sedimentation.

6. The study area apparently has the potential not only to be self sufficient but also to produce surplus foodgrains. However, as the model could not consider equity and distributional factors, it could only be concluded that surpluses were held by large land owners and found their way into outside market.

7. There was wide disparity among individual Panchayats in terms of resource availability and need. Densely populated Panchayats such as Pokhara, D. Pokhari, Sarangkat and Kaskikot were found to be deficient in most of the output items. Panchayats with relatively lower population pressure were observed to possess surplus production potential.

8. Public lands were shown to be managed inefficiently. The solution supported agro-pastoral and agro-forestry systems of management on all types of public land to increase per unit productivity. Part of the forestland was suitable for commercial management

(Appendix D lists potential fodder and fuelwood trees.

9. Introduction of winter pasture in the fully irrigated arable land was suggested when the attempt was made to maximize animal forage and the solution still satisfied the calorie constraint. Rice technology with 50% improved varieties was found profitable but results on improved maize were not conclusive.

10. Improved breeds of buffalo, goat and cattle were included in most of the Panchayat plans. Sheep raising was rejected in many plans.

11. The use of multi-level planning indicated several advantages:
    (a) a drastic decrease in model size,
    (b) establishment of communication between two levels of planning,
    (c) enhancement of the concept of 'popular participation' in planning, and
    (d) mobilization of local resources and integration of activities over space by appreciating intimate linkages among resource elements.

Application of Results

Direct application of the results of this study is not suggested. This was not the intent of the study. However, given the fact that there are only few of this kind of studies for the watershed and none for the country, a significant implication of this study is possible.

Alarmingly low supply of animal forage and attribution of this factor to poor livestock productivity and consequent poverty among the people who depend on farming is often discussed as a cause and effect relationship in the hills. To improve this the attribution of top priority to AUY's maximization and the resultant feasibility of such a strategy as shown by this study could be termed as a relevant option to the resource managers.

Depletion of a major source of energy, namely forest, is appreciated by all. Uncontrolled grazing and tree felling are the causes. To rectify these malpractices, regulation and control of forest resources are recommended.

In addition to improving management technology, simultaneous reforms in planning techniques is thought to be crucial for improving resource productivity. In this regard, usefuleness of the multi-level planning approach shown through the study could be helpful.

Recent changes in forest legislation promotes the private ownership of forests. In the wake of such developments, demands for the knowledge of the most appropriate type of investments in forestry will increase. The identification of possible activities in this study might provide some guidelines.

The existing Phewa Tal Watershed management plan considers subwatershed level planning. However, local people and government line agencies consider Panchayats as the basic unit. Therefore to achieve an integration between subwatersheds and Panchayat the technique suggested by this study may be helpful.

The current Sixth Five Year Plan (1981-86) of Nepal heavily emphasizes the protection, conservation, and balanced development of the country's natural resources. In its basic principles, the plan states that ". . . in order to control and coordinate all the relevant institutions or units using land and also to check them from contaminating the atmosphere some legal provision will be made so that land could be used only on the basis of scientific land use classification . . .". Exercises such as (National Planning Commission, 1980) was accomplished through this study may translate the above policy into practice.

Farmer's cropping system techniques cannot be regarded as inappropriate based on the results of this study. Selected alternatives suggested that on the upland, maize/millet/grain legume rotation utilized the resources efficiently. It is the lowland where much improvement could be effected. Crop rotation having the inclusion of winter forage like *Trifolium repens* might prove appropriate. According to Pandey (1975-76) also lucern, oat and ryegrass were found to be promising during winter months.

Finally, this study implied that instead of looking for a complete solution for the country's local, regional/national problems, resource managers should first strive for partial solutions.

Limitations

1. The single-level formulation of linear programming model in this study could be considered relatively small (80 rows by 640 columns) as it could have been easily handled by

high speed computer. In such cases, direct method might have produced better results.

2. The relationship between Panchayat and watershed is not arranged in a perfect hierarchy, whereas subwatershed to watershed is. The multi-level planning application would have been more appropraite if the lower level planning unit were at the subwatershed level.

3. Multi-level planning might lead to a plan for an individual Panchayat's self sufficiency alone. If that happened in the Phewa Tal Watershed, where the resource endowment is highly non-uniform, it would lead to underutilization of resource potential. There may also be a problem of possible conflict in goal setting between the Panchayats and the Watershed.

4. The deterministic nature of LP models ignores risk and uncertainty and may lead to a resource management plan that may be unacceptable to the farmers and decision makers on the basis of their past experiences. Uncertainty in the model may be in the forecasted costs, yields, and prices for individual activities, in activity requirement for fixed resources, and in the total fixed and variable constraint levels.

5. The results suggested that the use of linear programming and related methods could improve the decision making system in natural resource management. However, this is tied to easy and economical accessibility to computer facilities which was not properly evaluated.

6. The assumption of uniformity in cost coefficients (the use of same unit costs) across the Panchayats may not be true.

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APPENDIX A

LAND MANAGEMENT ALTERNATIVES AND PRODUCT TYPES

a. <u>Land Management Alternatives</u>*

<u>Range Land</u>

X_1 - Do Nothing - all animals (DNAA).

Range is severely deteriorated due to overgrazing. Estimated dry matter (DM) production is 1.37 tons/ha at 70% utilization. At the rates of 48% TDN content, and per Animal Unit (AU) consumption rate of 1.083 ton TDN per year, the carrying capacity is 0.64 AUY. Yearly renovation of fences cost Rs. 80/ha. Sixty-seven labor days are involved. Thirty point two tons/ha of sediment is produced.

X_2 - Fencing, hand harvesting of forage - all animals (FHAA).

Range is protected from grazing by erecting either barbed wire or stone walled fencing. DM production is estimated at 5.4 tons/ha. Assuming 48% TDN content, and 1.031 tons of TDN requirement per AU per year the carrying capacity is 2.40 AUYs. The budget requirement (average amount for 15 years) is Rs. 182 out of which Rs. 146 is cash for subsidy. One hundred thirty mandays of labor are expected to be used. Two point zero tons of compost is applied, Sedimentation is 6.2 tons/ha.

X_3 - Fencing, revegetation and rotation grazing with improved buffalo (FRRI)

*All alternatives refer to one ha. of land.

Range is closed for grazing. Light seeding of grasses and legumes is carried out. Average yearly DM production is about 6.50 tons/ha, assuming 60% utilization rate. At 50% TDN content and at 1.031 tons/AU/year, the estimated carrying capacity is 3.05 AUYs. The budgetary requirement is Rs. 339 out of which Rs. 271 is government support in the form of cash. Labor requirement is 185 mandays. This activity requires 2.5 tons of compost. Nine point five tons/ha of sedimentation is estimated.

X_4 - Fencing, revegetation and stall feeding - all animals (FRSA)
Range is reseeded with suitable grasses and legumes after fencing. Seven point zero tons/ha of DM production is estimated. The estimated carrying capacity based on the assumptions in activity X_2 is expected to be 3.36 AUYs. Rs. 254 is to be budgeted for each year. Labor and credit requirements are 165 mandays and Rs. 203 per year respectively. This alternative requires 3 tons of compost. Sedimentation is 8.0 tons/ha.

X_5 - Fencing, overstory fodder trees, understory grass revegetation. Stall feeding, stall feeding all animals (FOUS)
Range land is prepared for silvi-pastural activities. Suitable fodder trees are first planted at wide spacing. It is followed by plantation with grass stolons. DM production including forage leaves is estimated to be about 7.2 tons/ha. The carrying capacity is calculated to be 3.45 AUYs. Rs. 268 is the annual budget out of which Rs. 241 is cash. Two m^3 of wood is also produced. Labor requirement is expected to

be 175 labor days, and compost is 2.5 tons per hectare. Sediment production is 6.0 tons/ha.

X_6 - Fencing, overstory fodder trees, understory grass revegetation, stall feeding - Improved buffalo and goats (FOUI)

Operations are similar to X_5. The difference is in that only improved breeds of buffalo and goats are fed. DM production is estimated to be the same, i.e., 7.2 tons/ha. The carrying capacity is again 336 AUYs. The costs would rise to Rs. 300 and so would credit and labor requirements. Rs. 270 and 180 mandays respectively. Compost requirement is 2.5 tons/hectare. Sediment and fuelwood productions are same as in X_5.

X_7 - Fencing, fodder tree plantation, stall feeding - all animals (FNSA)

Rangeland would be prepared exclusively for tree plantation. Suitable fodder trees would be planted to achieve full canopy cover. Fodder leaves could be harvested from fifth year onward. Expected dry matter production is 7 tons/ha, assuming 70% utilization rate, 5.6% TDN content and 1.031 ton/AUY/year, the carrying capacity is expected to be 2.66 AUYs in a typical year budget is Rs. 285 and credit is Rs. 228. One hundred seventy-eight labor days are involved. Two point five tons of compost is also expected to be applied. Ten point five tons of sediment and 2 m^3 of fuelwood are expected.

X_8 - Fencing, mixed tree plantation (fodder, fuelwood and fruit trees) and stall feeding by all animals (FMSA)

This concept of land management is technically known as Agro-silvi-pastural system. Trees are planted either in equal proportion or in different ratios depending upon the land suitability. Dual purpose trees (e.g., *Leucaena leucocephala*) are planted where suitable. Plantation of fruit trees is to provide some cash to the community. The dry matter production is estimated to be 4.65 tons/ha. The carrying capacity is 2.45 AUY/ha. The budget requirement is Rs. 354 and cash, labor and compost are respectively Rs. 319, 191 mandays and 2.3 tons. Fruit products provide Rs. 85/year of revenues. Three point thirty-three m^3 of fuel-wood and 8.5 tons of sediment are produced.

X_9 - Fencing, revegetation with improved grasses and legumes, stall feeding to improved buffalo, selected cattle and improved goats (FRIC)

Rangeland is managed for most productive animals. Proven grass species such as *Pennisetum*, *sorgum* and *Eucleana* species are planted. DM production is estimated to be 7.5 tons/ha. The carrying capacity is 348 AUY/ha. This operation is budgeted for Rs. 284 annually, out of which cash requirement is Rs. 227. Labor days are 179 mandays and compost 3 tons. Sediment production is 7.5 tons/ha.

X_{10}- No fencing, above story fodder trees, understory native grasses. Rotation grazing by all animals (NFUR)

Instead of erecting fences, in this alternative, human guards are employed. Suitable fodder trees are first planted followed by seeding or plantation of improved grasses.

The DM production is estimated to be 4.5 tons/ha. The carrying capacity is calculated to be 2.3 AUY. This alternative requires a budget of Rs. 281 out of which Rs. 231 is cash support. Labor requirement is 353 mandays which is high compared to other alternatives. Compost requirement is 2.5 tons/ha. One m^3 of fuelwood and 12 tons of sediment are estimated.

X_{11}- Fencing, Napier Grass (*Pennisetum purpureum*) plantation, stall feeding all animals (FNSF)

As in most alternatives, rangeland is cleared off grazing. Land is thoroughly prepared. The grass cuttings are carefully planted. Relatively high dose of compost (4.5 ton/ha) is applied. The estimated DM production is 8.0 tons/ha. The carrying capacity is 4.13 AUY per ha per year. The budget is Rs. 526 mandays of labor requirement (estimated). The amount of credit requirement is Rs. 383. Seven tons of sediment is produced.

X_{12}- Fencing, planting of summer-winter annual grasses, stall feeding (FAGS)

Annual forage crops such as *Eucleana maxicana (Teosinte)*, *Sorghum sudanensis* (Sudangrass) and *Pennestetum pedicillatum*, and winter growing leguminous forage crops such as *Trifolium* sp., *Melilotus* sp. and *Pisum* sp. are planted. The dry matter production is estimated 5.0 tons/ha with a carrying capacity of 3.21 AUY/ha. This activity will require an annual budget of Rs. 392. Labor and credit requirements would be 270 mandays and Rs. 314. The amount of compost is 3 tons per ha.

Eight point five tons of sediment is produced.

Forest Land

X_{13}- Do Nothing - Uncontrolled grazing, fuelwood, and timber harvesting (DUFT)

Heavy use of the forest continues. Grazing by all types of animals, harvesting of fuelwood and timber is allowed. Forage dry matter production is estimated at 0.61 tons/ha. The carrying capacity is 0.29 AUY/ha. Six point five cub. m. of fuelwood and timber products are expected annually. It will yield 7.2 tons/ha of sediment. The requirements for budget, and labor are Rs. 270, and 112 mandays, respectively. Sediment production is 7.2 tons/ha.

X_{14}- Regulated grazing and controlled harvesting of fuelwood timber (RGFT)

Allowing grazing as per the carrying capacity and in-appropriate season is accompanied by strict control on fuel-wood and timber output. Forage dry matter production would improve due to grazing management, with an average annual production of 1.80 tons/ha. The carrying capacity is .88 AUY/ha. Fuelwood and timber products would amount to 14 cub. m./ha. Annual budget, labor and cash requirements are Rs. 588, 118 mandays and Rs. 371. Sedimentation of 6 tons/ha is expected.

X_{15}- Understory revegetation by grasses and legumes, regulation of fuelwood and timber products (URGL)

Forest is cleared off of undesired shurbs and weedy plants.

In the beginning of rainfall grasses are seeded, which are expected to be usable within a year. Estimated dry matter production is 2.25 tons/ha. The carrying capacity is 1.08 AUY/ha. Wood production is 14 cub. m. per ha. This activity is estimated to require a budget of Rs. 657, 131 mandays of labor and a cash requirement of Rs. 491. Five point five tons/ha of sediment is expected.

X_{16}- Enrichment plantation of woodland with fodder trees and grasses (NPFG)

Fodder trees are planted where tree density is light. Native grasses are enriched with exotic grasses. After five years fodder trees would yield forage and make up the losses in grass forage yield. Annual herbage production is estimated to be 2.5/tons/ha (DM). The carrying capacity is 7.20 AUY/ha. Due to the dual nature of fodder trees fuelwood production would go up to 15 cub. m./ha/year. The budget, credit and labor requirements are Rs. 687, Rs. 518 and 137 mandays respectively. Six point zoer tons of sediment is expected.

X_{17}- Commercial management of the forest for fuelwood and timber products (CMFT)

Currently unmanaged forest is converted to managed forest through protection from grazing, control of fodder and fuel-wood removal, and sustained yield management. One point two tons/ha of herbage production is expected to feed 0.58 AUY/ha/year. Timber production is 16.5 cub. m. Inputs for management are Rs. 722 as annual budget, Rs. 522 of which is in cash and 148 mandays of labor.

Scrub Land

X_{18}- Do Nothing. Uncontrolled grazing, collection of tree leaves and fuelwood (DNUC)

Currently a hectare of scrub land produces 850 kgs of forage dry matter and 3 cub. m. of fuelwood. On a long term basis the average forage and fuelwood production are estimated to be .82 tons/ha to carry 0.39 AU/year and 3.0 cub. m/ha respectively. The cost of extracting these resources is Rs. 60/ha. Labor requirement is 35 mandays. It produces 17.5 tons/ha of sediment.

X_{19}- Scrub clearing, fencing and raising of improved pasture for rotation grazing. (CPMR)

Scrub land is prepared through the removal of undesired plants. This is followed by planting improved grasses and legumes. Initially yield will be lower but the long term average would be 4 tons/ha. The carrying capacity is 2.04 AU/yr. This will require a budget of Rs. 554, Rs. 471 in terms of direct cash. One hundred eighteen mandays of labor are involved. Sediment production is 12 tons/ha.

X_{20} Sivi-pastural management (fodder trees plus exotic grasses) stall feeding. (SPMS)

This alternative involves managing potential existing trees and establishing of understory grasses. Estimated dry matter production is 3.7 tons/ha to maintain 1.78 AUYs. The annual budget, credit and labor requirements are respectively Rs. 508, Rs. 432 and 108 mandays.

X_{21}- Agri-pasture (Fruit orchard and improved grasses). (APMI)

Horticultural plants are established after clearing the bushes. Improved grasses and legumes form understory vegetation. Annual forage production (DM) is 3 tons/ha. The carrying capacity is 1.44 AU/year. Computed avearge revenue from the fruit selling is Rs. 373. The budget is Rs. 810 out of which Rs. 688 is cash requirement. One hundred seventy-six mandays of human labor is needed. This alternative is estimated to yield 11 tons/ha of sediment yield.

X_{22}- Fencing overstory fuelwood-understory pasture management. (FFUP)
Fast growing fuelwood species namely, *Alnus nepalensis* and *Alnus rubra* are planted in wide spacing patterns. Grasses are established between rows. Forage dry matter production is estimated as 3.0 tons/ha. The carrying capacity is 1.44 AU/year. Fuelwood production is 6 cub. m./ha. It will require a budget of Rs. 515, cash amount of Rs. 438, and 116 days of labor. Sediment production rate is 10 tons/ha.

X_{23}- Mixed tree plantation combined with native grasses, stall feeding. (BCUS)
Scrub land is excluded from grazing. Trees of fodder, fuelwood, fruit types are planted initially at the rate of 400 trees per ha. Native grasses are managed only for stall feeding. *Leucaena leucocephala* could be a potential multi-purpose tree. The combined effect of fodder trees and grass would produce a forage dry matter production of 4 cub. m./ha to support 2.16 AU/year. Fuelwood production is expected to be 4.5 tons/ha. The budget, cash, and labor requirements are Rs. 612, Rs. 520 and 138 mandays.

Silvi-pasture Land

X_{24}- Do Nothing - Hand cutting of predominantly native grasses under mixed tree plantation. (DNHS)

This alternative, in itself an improved practice recently introduced is characterized by planting multi-nature plants on the same unit of land. Understory vegetation is generally native vegetation. Fuelwood trees predominate. During six years of its existence forage production is declining due to canopy cover. Long term forage dry matter production is 4.7 tons/ha. It can feed 2.26 AUS in a year. It is also expected to yield 2 cub. m. of wood and Rs. 150 of cash trhough the selling of fruits. The budget amount is Rs. 420 with 92 mandays of human labor involved. The sediment production is 2.0 tons/ha.

X_{25}- Replacement of native grasses with improved pasture species. (RNIL)

The aim of this alternative is to improve the plantation area through planting new grasses and also carrying out limited thinning. Forage dry matter production estimate is 6.5 tons/ha or 3.41 AU/ha/year. The 2 cub. m. yield of fuelwood and Rs. 150 is fruit revenue are not affected. Rs. 637 of budget money, 144 mandays of labor and Rs. 541 in credit requirement are estimated.

X_{26}- Enrichment plantation with more trees, phasing out of under-stroy grassy vegetation. (EPFF)

More fodder and fuelwood trees are planned. Understory herbage production would decline to 3.25 tons/ha. The carrying capacity would be 1.61 AU/ha/year. The fuelwood production would go up to 5.2 cub. m/ha. Program needs a budget of Rs. 604, Rs. 513 in cash and 136 mandays of human labor.

Wasteland

X_{27}- Do Nothing - Excessive sedimentation production (DNES)

Land suffers from landslides and soil erosion. Sediment production is 37.8 ton/ha. Negligible grazing or forage material exists. One hundred fifty kgm per ha. Farmers invest Rs. 30 to extract this resource. It takes 20 days of labor.

X_{28}- Fencing, checkdam construction and plantation of improved grasses, legumes and fodder trees (CDCG)

Area is fenced off. Series of earth and stone check dams are constructed, to stablize the slopes. Improved grasses, legumes and fodder trees are planted. Two tons of forage dry matter production (.96 AUY) and 0.5 cub. m. of wood matter are estimated. The budget, labor and credit requirements are Rs. 4,130, 774 mandays and Rs. 3,720, respectively. Sediment yield is 11.5 tons/ha.

X_{29}- Fencing, check dam construction, and only fodder tree plantation (CDFN)

It differs from X_{28} in that here only fodder trees at a rate of 800 plants/ha are planted. Three tons forage dry matter (1.04 AUY) is expected. Zero point five cub. m. of fuelwood yield is also produced. The budget amount is Rs. 4,100 out of which Rs. 3,690 is cash. Seven hundred and sixty-eight mandays of human labor are involved. Sediment production is 12 tons/ha.

Cultivated Type 'A' (fully irrigated) Land

X_{30}- Do Nothing - Main Rice-wheat (50%), main Rice-fallow (50%) (DNPW)

Current practice of growing rice during summer/fall and wheat on partial plots during spring is retained. A total of 5.2 megacalories equivalent of food grains are produced. One point thirty AUYs are also obtained. It takes a budget of Rs 2,600 out of which Rs. 324 is credit component. Two hundred fifty m. days of human labor and 6 tons of compost are other requirements.

X_{31}- Improved (I) Rice - I. wheat (25%); I. Rice-grains legumes (25%); Local (L) Rice - I. Wheat (25%), L. Rice - Winter Pasture (25%) (IPWLP)

This alternative introduces new strains of rice, growing of grain legumes and winter pasture in the cropping pattern. Combined porduction of food grains in terms of megacalories is 7.26. Forage production remains at 1.296 AUYs. Budget requirement is Rs. 2,896, credit Rs. 724 and human labor worth of 290 days. The compost needed is 9.5 tons/ha.

X_{32}- Early L. Rice - I. Rice. G. Legumes; L. Rice - I. Wheat - G. Legumes, and L. Rice - Winter Pasture (LPWLP)

This alternative includes early paddy which is already grown by some farmers of the area plus all the features of X_{31}. Food grain production is equvalent to 7.1 mega calories. One point forty-five AUYs are also produced. It will demand a budget of Rs. 3,928 out of which Rs. 982 is cash. Labor requriements is 217 mandays and compost 9.0 m. tons.

X_{33} - Local Rice - winter pasture (50%) - Improved paddy - Winter pasture (PWPA).

This option recommends the growing of winter pasture on the entire land. Only 4.46 mega calories worth of food grains are produced. However, 312 AUY worth of forage is also produced. Program needs a budget of Rs. 2,170, out of which Rs. 543 is cash. Two hundred seventeen mandays of labor and 9.5 tons of compost are also required.

X_{34} - E. Rice - Main Rice - G. Legumes (L) (50%), E. Rice - Main Rice - G. Legumes (I) - 50% (EPMPL)

This alternative's major component is rice. Both local and improved varieties are included. Eight point nine mega calories equivalent of food grains are produced. One point thirty-eight AUYs are also produced. Rs. 3,872 is the budget estimate and credit need is Rs. 582 mandays and 11 tons of compost are also involved.

X_{35} - E. Rice - Main Rice - Winter Pature (I) (EPMPP)

It differs from X_{34} in that it uses only improved varieties of rice. As a result, food grain production is pushed up to the equivalent of 9.5 mega calories. AUY production is also up to 1.60 AU/year/ha. This requires a budget of Rs. 3,750, credit amounting to Rs. 935 and 374 mandays of human labor. Fourteen tons of compost is needed.

X_{36} - E. Maize - Main Rice (L) - W. Pasture (50%), E. Maize (L) - Main Rice (L) - Green manure (EMMPP)

This laternative limits the coverage by improved varieties to 50% and introduces green manures to supplement the compost requirements. Eight point four mega calories equivalent of food grains are produced. One point thirty-six AUY is also produced. Compost requirement is only 4 tons/ha. Budget credit and labor requirements are respectively Rs. 3,698, and 370 mandays. Compost requirements is 4 tons/ha.

Cultivated Type 'B' (partially irrigated) Land

X_{37}- Do Nothing - Rice-wheat (60%). Rice-fallow (40%) [DNPWF]

Only rice gets nearly enough irrigation water. Rice varieties are local where as wheat breeds are improved. Five point seven mega calorie equivalent of food grains are produced plus 1 AUY of forage. This alternative is budgeted for Rs. 3,000. Rs. 450 comes through credit. Two hundred fifty-six days of labor and 7 tons of compost is also required.

X_{38}- L. Rice - I. Wheat (50%), I. Rice - I Wheat (50%). [IPIW]

Only improved varieties of wheat are grown, due to the overwhelming acceptance of variety RR-21. Eight point four mega calories is the value of food grains and 1.31 AUYs are also produced. Input requirements are Rs. 3,209 as budget, Rs. 802 as credit and 321 mandays as human labor. Eleven tons of compost are required.

X_{39}- L. Rice - G. Legumes/oilseeds (50%), I. Rice - I. Grain Legumes/oilseeds (50%) [PLOI]

This alternative includes rapeseed and mustard (both oilseed crops) to meet farmer's own needs. Grain legumes are also important to meet their protein needs. Food grain production is equal to 7.02 mega calories. One point zero three AUs can be fed per year out of the forage produced. Budget credit and labor requirements are Rs. 3,308, 331 mandays and Rs. 827 respectively. Twelve tons of compost is also needed.

X_{40}- L. Rice - L. Potato - Green Manure (50%), I. Rice - I. wheat - Green Manure [PPWG]

Potato, a high calorie yielding crop, is included in this alternative. Other crops are rice and fertility enriching green manures. A high amount of food grain worth 10.33 mega calories is produced, 1.07 AUYs are also estimated. Rs. 4,065 is needed as an annual budget, Rs. 7020 as credit, and 406 mandays of labor. Sediment production is 10.0 tons/ha.

X_{41}- L. Rice - Winter Forage (50%), I. Rice - Winter Forage (50%) [PIWF]

This alternative considers possibility of growing winter forage during winter season. The posable forage species are listed in Appendix D. The food production is equal to 4.1 mega calories. Two point forty AUYs worth of forage can also be produced. It requires an annual budget of Rs. 2,506 and 251 mandays and Rs. 626 as credit and 5 tons as compost.

<u>Cultivated Type 'C' (rainfed) Land</u>

X_{42}- Do Nothing - L. Maize - L. Millet - Legume grains (70%), Maize-millet-fallow (30%) [DNMM]

Maize is the main crop in the rainfed terraces. Millet is overlapped in maize field. Seven point six hundred and twenty-four mega calories worth of food grains are produced.

Forage equivalent of 1.2 AUYs is also produced. Annual budget is Rs. 4,000, credit Rs. 1,000 and labor 280 mandays. Nine tons of composts are required. However, a high 17.5 tons of sediment production per ha is also estimated.

X_{43}- L. Maize - L. Millet - I. Wheat, R. Maize - New Millet - Wheat (MMWI)

The main aim of this alternative is to increase production and also to lengthen the period of ground cover to reduce sediment production, which is expected to remain at 13 tons/ha. Rs. 4,966 is the estimated annual budget, 436 mandays, annual labor and Rs. 1,240 as credit requirements. Six tons/ha of compost is also required. Food grain and forage productions are equivalent to 10.4 mega calories and 1.22 AUYs respectively.

X_{44}- I. Potato - L. Upland Rice - G. Legumes (50%), I. Potato - I. Upland Rice - Green Pasture (oats/barley) 50% [PBGL]

This alternative emphasizes both increase in total calorie production, and reduction in sedimentation through increase in crop cover. The calorie production is 9.14 mega calories, and sedimentation 11.5 tons/ha. Forage production is equal to 1.4 AUYs. It is estimated that to carry out these activities, Rs. 7,724 as budget, Rs. 1,933 as credit, and 662 mandays of human labor would be required. Fourteen tons of compost is needed.

X_{45}- L. Maize/Legumes - I. Wheat, I. Maize/Legumes - I. Wheat/peas [MLMI]

This operation is already in practice at some farms. It emphasizes mixed farming. Nine point seven hundred fifty-four mega calories worth of food grains are produced, along with AUYs equivalent to 1.25. Estimated annual budget is Rs. 4,295, credit is Rs. 1,070, labor 368 mandays and 11 tons of compost. It will also yield 12 tons/ha of sediment.

X_{46}- I. maize, I. millet - Winter legumes and grasses [MMGG]

This alternative recommends complete switch over to improved varieties. Inclusion of legumes to provide forage production is also proposed. Food grain production is projected to be 7.6 mega calories and AUYs to be 1.25. Annual budget, labor, credit and compost requirements are Rs. 3,489, 299 mandays, Rs. 872 and 8 tons respectively. Sediment production is 10 tons/ha.

X_{47}- L. upland rice - Grain legumes - I. potato [BPGP]

Broadcast rice is followed by short duration grain legumes. Potato is the winter crop. Food grain production in terms of food calorie is 7.6 mega calories. Forage production is equal to 1.15 AUYs. It will require an annual budget of Rs. 7,320 out of which Rs. 1,830 is to be cash payment. Six hundred and twenty-seven labor days and 13 tons of compost are also involved. Sediment production is 11.5 tons/ha.

b. Product Types

X_{48}- Old cattle -

Cattle are reared mainly for milk, power, and compost. Oxen provide most of the power for agricultural operations. One unit (AU) of local cattle consumes 1,083 kgms of TDN in a year. The life of a cow is 10-15 years. During that period on an average it produces 215 litres of milke/yr., and 2.6 tons of compost. Besides feed costs, Rs. 443/yr is incurred as management cost. Expected gross return is Rs. 1,139/yr. Cash and labor requirements are Rs. 396 and 73 mandays respectively.

X_{49}- New cattle -

New cattle are bred through artificial insemination using half bred (F_1) Jersey bull. One thousand, one hundred ninty one kgms TDN is expected to be consumed by one new cow AU per year. Milk production is increased to 355 litres/year, and compost 2.7 tons/year. The estimated management cost is Rs. 580 and gross revenue Rs. 1,989 in a typical year. Labor and cash requirements are respectively 91 mandays and Rs. 994.

X_{50}- Old Buffalo -

Buffalo are the most useful animals. Milk, meat, some draft power and compost are the common products. One AU of local buffalo consumes 1,083 kgms of TDN. Four hundred forty litres of milk, 125 kgms of meat, and 5.0 tons of compost are produced in a year. Rs. 550 is the management cost and gross revenue is Rs. 1,775. Labor and cash requirements are respectively 122 mandays and Rs. 532.

X_{51}- New buffalo -

Cross breeding with improved Murrah breed would be used to generate these buffalo. One thousand two hundred twenty-four kgms of TDN would be consumed by each AU/yr. Milk production would go up to 870 litres. Annual cost for management is Rs. 1,208 and Rs. 3,230 is the expected gross revenue. Labor and cash requirements are 146 mandays and Rs. 1,440 respectively. Compost production is 5.5 tons/year/AU.

X_{52}- Old goats -

Goats are mainly reared for meat purposes. The forage consumption rate is 1,083 kgms of TDN per AU. Each AU of goat yields about 27 kgms of meat, costs about Rs. 424 and gives a gross return of Rs. 1,394. Compost production is 1.5 tons/yr/AUY. Cash and labor requirements are respectively Rs. 128 and 36 mandays respectively.

X_{53}- New goats -

Cross bred 'Jamanapari' bucks are used to upgrade old goats. Per AU meat production goes up to 35/kg/year. One AU of new goat needs 1,164 kgms of TDN, Rs. 616 as management cost, 140 mandays as labor, and Rs. 257 as cash requirements per year. Compost production per AUY remains 1.5 tons. Gross revenue is Rs. 1,444.

X_{54}- Old sheep -

Sheep rearing is performed by only a handful of farmers. One AU of sheep consumes 1,083 kgms of TDN, costs about Rs. 532, takes about 42 mandays of labor and Rs. 167 as cash. Rs. 659 is the expected gross return in a typical year. Twenty kgms of meat and 4 kgms of wool are expected from each AU of sheep.

X_{55}- Rice Calories -

One ton of processed rice (2.38 tons of gross produce) yields

3.54 mega calories of energy. Management costs are incorporated in the cost of production of crops. Processing, marketing and storage costs are not included. The gross return is estimated to be Rs. 7,200.6/mega calories.

X_{56}- Maize calories -

The conversion factor is 3.49 mega calories for a ton of processed maize (1.39 ton gross). The gross return is Rs. 845/m. calories.

X_{57}- Wheat calories -

Three point thirty-two mega calories can be obtained out of one ton of processed wheat (1.39 ton gross). The gross return is Rs. 1,021/mega calories.

X_{58}- Millet calories -

Conversion factor is the same as in wheat. However, the gross return is Rs. 852.4/m. cal.

X_{59}- Other calories -

It includes barley, buckwheat, legume grains and potatoes whose caloric conversion factors are respectively 3.4, 3.32, 3.85 and 0.82 mega calories for each ton of processed products. On combining in the proportion they are expected to be produced the gross revenue is calculated to be Rs. 1,889.5/m. cal.

X_{60}- Fuelwood and Timber Products -

It is a major product from the forest land. Costs are included in the cost of production estimates. Rs. 499 per cubic meter is the expected revenue.

X_{61}- Sediments from eight land types. No revenues expected.
X_{68}

X_{69}- Milk is an essential product. It is one of the major sources of off-farm income. It is priced at Rs. 3/litre. Both cattle and buffalo produce milke. Goat milk is not common.

X_{70}- Buffalo meat -

Buffalo meat is increasingly becoming popular. It sells at Rs. 10/kg.

X_{71}- Goat meat -

Goat meat is the most popular meat. It is sold at the rate of Rs. 20/kg.

X_{72}- Sheep meat -

Sheep meat is not very common in the study area. One kgm of sheep meat sells for Rs. 10.

X_{73}- Sheep wool -

Sheep wool is widely sought after. The price for 1 kgm of raw wool is Rs. 15.

X_{74}- These seven products are of common type in that they all are
X_{80} used for the same purpose, i.e., to provide nutrients to the plants. They are separated in the model as the rates of production vary. Buffalo produce the highest amount (5 - 5.5 tons/AUY) because they can convert the bedding materials into compost in highest amount. Cattle are medium producers (2 - 2.5 tons/AUY). Goats and sheep produce between 1 - 1.5 tons/AUY.

APPENDIX B

PROJECTIONS OF PRODUCTION RATES FOR VARIOUS MANAGEMENT ALTERNATIVES

Units: F - Forage - M. tons (dry matter per ha[1]/
W - Fuelwood & timber products cub. m.
S - Sediment tons/ha
O - Others in cash (Rs./ha)

1. Range Land

S. No.	Management Code*		YR 1	YR 2	YR 3	[0]YR 4	YR 5	YR 6-10	YR 11-15	Average
		F	1.37	1.37	1.37	1.37	1.37	1.35	1.34	1.35
X_1	DNAA	W	-	-	-	-	-	-	-	-
		S	30.2	-	-	-	-	-	-	30.2
		O	-	-	-	-	-	-	-	-
		F	2.75	4.11	5.4	5.53	5.6	5.6	5.6	5.0
X_2	FHAA	N	-	-	-	-	-	-	-	-
		S	-	-	-	-	-	-	-	6.2
		O	-	-	-	-	-	-	-	-
		F	2.30	4.0	5.50	6.50	7.0	7.0	7.0	6.35
X_3	FRRI	W	-	-	-	-	-	-	-	-
		S	-	-	-	-	-	-	-	9.5
		O	-	-	-	-	-	-	-	-
		F	2.80	4.5	6.0	7.0	7.5	7.5	7.5	7.0
X_4	FRSA	W	-	-	-	-	-	-	-	-
		S	-	-	-	-	-	-	-	8.0
		O	-	-	-	-	-	-	-	-
		F	2.25	4.25	5.15	6.0	7.25	8.0	9.0	7.2
X_5	FOUS	W	-	-	-	-	-	3.5	4.5	2.0
		S	-	-	-	-	-	-	-	6.0
		O	-	-	-	-	-	-	-	-
		F	2.25	4.25	5.15	6.0	7.25	8.5	9.0	7.0

1. Range Land (continued)

S. No.	Management	Code*	YR 1	Yr 2	YR 3	0YR 4	YR 5	YR 6-10	YR 11-15	Average
X_6	OUI	W	-	-	-	-	-	3.5	4.5	2.0
		S	-	-	-	-	-	-	-	6.0
		O	-	-	-	-	-	-	-	-
		F	2.0	3.75	4.0	4.5	5.5	7.5	8.0	6.5
X_7	FNSA	W	-	-	-	-	-	3.5	4.5	2.0
		S	-	-	-	-	-	-	-	10.5
		O	-	-	-	-	-	-	-	-
		F	2.0	3.75	4.1	4.65	5.0	5.5	6.0	5.1
X_8	FMSA	W	-	-	-	-	-	4.0	6.0	3.33
		S	-	-	-	-	-	-	-	8.5
		O	-	-	-	-	-	105.	150.	85.
		F	2.0	4.5	6.0	8.0	80.	8.	8.	7.25
X_9	FRIC	W	-	-	-	-	-	-	-	-
		S	-	-	-	-	-	-	-	7.5
		O	-	-	-	-	-	-	-	-
		F	1.5	2.75	3.5	4.0	5.0	5.5	5.5	4.8
X_{10}	NFUR	W	-	-	-	-	-	1	2.0	1.0
		S	-	-	-	-	-	-	-	12.0
		O	-	-	-	-	-	-	-	-
		F	2.0	4.0	6.0	8.0	9.5	10.0	10.0	8.6
X_{11}	FNSF	W	-	-	-	-	-	-	-	-
		S	-	-	-	-	-	-	-	7.5
		O	-	-	-	-	-	-	-	-
		F	2.5	5.0	6.5	7.0	7.5	7.5	7.5	6.9
X_{12}	FAGS	W	-	-	-	-	-	-	-	-
		S	-	-	-	-	-	-	-	8.5
		O	-	-	-	-	-	-	-	-

*For detail see Appendix .

1/ Adjusted for 70 p.c. utilization percentage.

2. Forest Land

S. No.	Management Code*		YR 1	YR 2	YR 3	YR 4	YR 5	YR 6-10	YR 11-15	Average
X_{13}	DUFT	F	0.63	0.63	0.62	0.62	0.61	0.6	0.6	0.60
		W	7.0	7.0	7.0	7.0	7.0	6.5	6.5	6.50
		S	-	-	-	-	-	-	-	7.2
X_{14}	RGFT	F	1.2	1.3	1.5	1.7	1.9	2.0	2.0	1.84
		W	9.	9.	9.	9.	10.	15.	18.	14.
		S	-	-	-	-	-	-	-	6.0
X_{15}	URGL	F	1.0	1.2	1.7	1.8	2.0	2.5	2.5	2.25
		W	9.	9.	9.	9.	11.	15.	18.	14.
		S	1.2	-	-	-	-	-	-	5.5
X_{16}	NPFG	F	1.2	1.3	1.6	1.9	2.3	2.5	3.0	2.5
		W	9.	9.	9.	11.	13.	17.	15.	15.
		S	-	-	-	-	-	-	-	6.
X_{17}	CMFT	F	0.8	1.	1.1	1.2	1.25	1.25	1.25	1.2
		W	9.	9.	9.	12.	14.	20.	22.	16.5
		S	-	-	-	-	-	-	-	5.5

3. Scrub Land

S. No.	Management Code*		YR 1	YR 2	YR 3	YR 4	YR 5	YR 6	YR 7	YR 7
X_{18}	DNUC	F	0.85	0.85	0.83	0.82	0.80	0.80	0.80	0.82
		W	3.2	3.2	3.1	3.1	3.	2.9	2.8	3.
		S	-	-	-	-	-	-	-	17.5
X_{19}	CPMR	F	0.5	1.	2.5	3.5	4.	5.	5.5	4.25
		W	3.2	3.2	-	-	-	-	-	0.5
		S	-	-	-	-	-	-	-	12.
X_{20}	SPMS	F	1.	1.5	2.25	3.	3.5	4.5	5.0	3.7
		W	-	-	-	1.5	2.0	3.0	4.0	2.5
		S	-	-	-	-	-	-	-	10.5
X_{21}	APMI	F	1.0	1.5	2.25	3.25	4.0	4.	4.0	3.0
		W	-	-	-	-	-	-	-	0.5
		S	-	-	-	-	-	-	-	11.
		O	-	-	-	-	150	222.	536.	263.

3. Scrub Land (continued)

S. No.	Management Code*		YR 1	YR 2	YR 3	YR 4	YR 5	YR 6	YR 6	YR 7
		F	1.0	1.5	2.25	3.25	4.	4.	4.	3.0
X_{22}	FFUP	W	-	-	-	-	1.	3.	5.	2.7
		S	-	-	-	-	-	-	-	10.0
		F	1.0	1.5	2.25	3.8	4.5	5.2	5.5	4.5
X_{23}	BCUS	W	-	-	-	-	2.5	3.5	6.0	3.5
		S	-	-	-	-	-	-	-	11.5
		O	-	-	-	-	100.	150	360.	1750.

4. Silvi-pasture Land			YR 1	YR 2	YR 3	YR 4	YR 5	YR 6-10	YR 11-15	Average
		F	5.4	5.4	5.	5.	4.8	4.6	4.4	4.70
X_{24}	DNHS	W	-	-	-	1.	1.5	2.5	3.	2.
		S	-	-	-	-	-	-	-	2.0
		O	-	-	25.	60.	100.	150.	150.	112.
		F	3.	4.5	5.5	6.5	7.0	8.	8.	7.10
X_{25}	RNIL	W	-	-	-	1.	1.5	2.5	3.	2.
		S	-	-	-	-	-	-	-	2.2
		O	-	-	-	60.	100.	150.	150.	110.
		F	5.4	5.0	4.5	4.0	3.5	3.	2.5	3.35
X_{26}	EPFF	W	-	-	-	1.	1.5	5.	10.	5.2
		S	-	-	-	-	-	-	-	2.5
		O	-	-	-	60.	100.	150.	150.	110.

5. Waste Land			YR 1	YR 2	YR 3	YR 4	YR 5	YR 6-10	YR 11-15	Average
		F	0.20	0.20	0.18	0.18	0.05	0.12	0.10	0.15
X_{27}	DNES	W	-	-	-	-	-	-	-	.05
		S	-	-	-	-	-	-	-	37.8
		F	0.15	0.25	0.6	1.0	1.5	2.0	3.0	1.9
X_{28}	CDCG	W	-	-	-	-	-	-	1.5	0.5
		S	-	-	-	-	-	-	-	11.5
		F	0.15	0.25	0.6	1.0	1.8	2.25	3.5	2.17
X_{29}	CDFN	W	-	-	-	-	-	1.0	2.5	1.2
		S	-	-	-	-	-	-	-	12.0

Units: Food grains M. tons/ha
R - Rice; W - Wheat; M - Maize
L - Legume; PO - Potato; m - Millet
O - Other
Crop Residues AUY/ha
Sediments tons/ha

6. Cultivated Type 'A' Land

S. No.	Management Code*	Product	YR 1	YR 2	YR 3	YR 4	YR 5	YR 6-10	YR 11-15	Average
X_{30}	DNPW	R	2.0	2.0	2.05	2.1	2.12	2.2	2.3	2.15
		W	0.45	0.45	0.48	0.5	0.55	0.6	0.65	0.58
		AUY	0.99	1.19	1.22	1.25	1.28	1.33	1.38	1.30
		S	-	-	-	-	-	-	-	4.5
X_{31}	IPWLP	R	2.3	2.36	2.44	2.5	2.57	2.60	2.62	2.56
		W	0.8	0.8	0.83	0.86	0.9	0.95	0.95	0.91
		L	0.2	0.2	0.21	0.22	0.22	0.25	0.30	0.25
		AUY	0.9	1.12	1.2	1.26	1.29	1.32	1.42	1.296
		S	-	-	-	-	-	-	-	4.5
X_{32}	LPWLP	R	3.2	3.3	3.4	3.6	3.7	3.8	4.0	3.64
		W	0.4	0.41	0.43	0.45	0.48	0.5	0.52	0.48
		L	0.2	0.22	0.24	0.26	0.28	.3	.31	.28
		AUY	1.25	1.29	1.34	1.4	1.45	1.5	1.53	1.45
		S	-	-	-	-	-	-	-	4.5
X_{33}	PWPA	R	2.3	2.36	2.45	2.5	2.6	2.62	2.65	2.6
		AUY	1.83	2.75	3.68	3.7	3.76	3.77	3.78	3.12
		S	-	-	-	-	-	-	-	4.0
X_{34}	EPMPL	R	2.8	3.1	3.5	3.7	4.0	4.2	4.3	3.8
		L	0.7	0.75	0.8	0.85	0.9	1.0	1.0	0.85
		AUY	1.03	1.14	1.27	1.35	1.45	1.55	1.6	1.4
		S	-	-	-	-	-	-	-	4.
X_{35}	EPMPP	R	3.84	4.04	5.24	5.45	5.65	5.70	5.75	5.43
		AUY	0.99	1.05	1.55	1.6	1.67	1.68	1.70	1.60
		S	-	-	-	-	-	-	-	4.0

6. Cultivated Type 'A' Land (continued)

S. No.	Management Code*	Product	YR 1	YR 2	YR 3	YR 4	YR 5	YR 6-10	YR 11-15	Average
X_{36}	EMMPP	R	2.3	2.36	2.44	2.5	2.57	2.6	2.62	2.56
		M	1.2	1.3	1.45	1.55	1.60	1.7	1.8	1.52
		AUY	1.16	1.22	1.29	1.35	1.4	1.43	1.47	1.36
		S	-	-	-	-	-	-	-	4.

7. Cultivated Type 'B' Land

S. No.	Management Code*	Product	YR 1	YR 2	YR 3	YR 4	YR 5	YR 6-10	YR 11-15	Average
X_{37}	DNPWF	R	1.85	1.88	1.93	1.98	2.05	2.1	2.15	2.06
		W	0.7	0.72	0.75	0.80	0.85	0.9	.92	.86
		AUY	0.95	0.96	0.99	1.02	1.06	1.08	1.1	1.0
		S	-	-	-	-	-	-	-	8.0
X_{38}	IPIW	R	2.12	2.16	2.22	2.28	2.35	2.4	2.42	2.35
		W	1.45	1.52	1.60	1.70	1.75	1.80	1.80	1.75
		AUY	1.05	1.09	1.15	1.18	1.21	1.24	1.25	1.31
		S	-	-	-	-	-	-	-	9.0
X_{39}	PLOI	R	2.12	2.16	2.22	2.28	2.35	2.4	2.42	2.35
		L	.5	.52	.55	.57	.59	.61	.62	.58
		O	.2	.22	.25	.27	.29	.3	.31	.28
		AUY	0.90	.93	.97	1.0	1.03	1.05	1.07	1.03
		S	-	-	-	-	-	-	-	8.5
X_{40}	PPWG	R	2.12	2.16	2.22	2.28	2.35	2.4	2.42	2.35
		W	.72	.75	.80	.85	.87	.9	.92	.86
		PO	6.0	6.5	7.0	7.5	8.0	8.	8.	7.7
		AUY	0.91	.94	.99	1.02	1.06	1.1	1.15	1.1
		S	-	-	-	-	-	-	-	9.5
X_{41}	PIWF	R	2.12	2.16	2.22	2.28	2.35	2.4	2.42	2.35
		AUY	2.10	2.18	2.30	2.35	2.40	2.42	2.45	2.40
		S	-	-	-	-	-	-	-	6.5

8. Cultivated Type 'C' Land

S. No.	Management Code*	Product	YR 1	YR 2	YR 3	YR 4	YR 5	YR 6-10	YR 11-15	Average
X_{42}	DNMM	M	1.44	1.44	1.45	1.48	1.50	1.6	1.6	1.55
		m	.95	.96	.96	.95	.95	.95	.95	.95
		L	.40	.40	.40	.40	.40	.40	.40	.40
		AUY	1.20	1.20	1.2	1.21	1.23	1.27	1.27	1.22
		S	-	-	-	-	-	-	-	17.5
X_{43}	MMWI	M	1.44	1.50	1.60	1.70	1.80	1.85	1.90	1.80
		m	.95	.97	1.01	.05	1.1	1.2	1.25	1.1
		W	1.15	1.20	1.26	1.32	1.38	1.4	1.40	1.35
		AUY	1.20	1.21	1.22	1.24	1.25	1.25	1.25	1.22
		S	-	-	-	-	-	-	-	11.5
X_{44}	PBGL	R	1.0	1.05	1.12	1.22	1.35	1.40	1.41	1.29
		L	0.60	.65	.75	.80	.85	.90	.90	.85
		PO	8.0	8.5	9.0	9.2	9.5	9.5	9.5	9.0
		AUY	1.	1.1	1.2	1.3	1.35	1.5	1.55	1.4
		S	-	-	-	-	-	-	-	11.5
X_{45}	MLWI	M	1.30	1.35	1.44	1.53	1.62	1.67	1.67	1.62
		L	.60	.65	.75	.80	.85	.90	.90	.85
		W	1.15	1.20	1.26	1.32	1.38	1.40	1.40	1.35
		AUY	1.10	1.11	1.20	1.25	1.30	1.30	1.30	1.25
		S	-	-	-	-	-	-	-	12.
X_{46}	MMGG	M	1.50	1.55	1.70	1.80	1.9	1.95	2.0	1.90
		m	0.90	.92	.95	1.	1.1	1.2	1.25	1.10
		AUY	1.30	1.31	1.32	1.35	1.39	1.45	1.50	1.35
		S	-	-	-	-	-	-	-	10.
X_{47}	BPGP	R	0.95	1.	1.07	1.17	1.25	1.25	1.25	1.2
		L	0.62	.67	.77	.82	.87	.92	.92	.89
		PO	8.	8.5	9.	9.2	9.5	9.5	9.5	9.
		AUY	1.12	1.13	1.14	1.15	1.16	1.16	1.18	1.15
		S	-	-	-	-	-	-	-	11.5

APPENDIX C

Elements of the objective function, management cost (budget), cash, labor and compost requirements.
Units: Budget - Rs. '000; Cash - Rs '000; labor - X'000; Mandays; Compost - M. tons.

	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	X_{11}	X_{12}	X_{13}	X_{14}	X_{15}	X_{16}	X_{17}	X_{18}	X_{19}	X_{20}	X_{21}	X_{22}	X_{23}	X_{24}	X_{25}	X_{26}	X_{27}
1. Budget	.08	.182	.339	.254	.268	.30	.285	.354	.284	.281	.526	.392	.27	.588	.657	.687	.722	.06	.554	.508	.810	.515	.612	.420	.637	.604	.03
2. Labor	.067	.130	.186	.165	.175	.180	.178	.191	.179	.270	.240	.270	.112	.118	.131	.137	.148	.035	.118	.114	.176	.116	.138	.092	.144	.136	.02
3. Cash	0.	.146	.271	.203	.241	.270	.228	.234	.227	.253	.383	.253	0.	.471	.491	.518	.522	0.	.477	.432	.688	.438	.345	0.	.431	.413	0.
4. Compost	0.	2.	2.5	3.	2.5	2.2	2.5	2.3	3.	2.5	4.5	2.5	0.	-	-	-	-	0.	-	-	-	-	-	-	-	-	-
5. Obj. Function Value	.08	.182	.339	.254	.268	.30	.285	.354	.284	.281	.526	.392	.27	.588	.657	.687	.722	.035	.554	.508	.810	.515	.612	.420	.637	.604	.03

	X_{28}	X_{29}	X_{30}	X_{31}	X_{32}	X_{33}	X_{34}	X_{35}	X_{36}	X_{37}	X_{38}	X_{39}	X_{40}	X_{41}	X_{42}	X_{43}	X_{44}	X_{45}	X_{46}	X_{47}	X_{48}	X_{49}	X_{50}	X_{51}
1. Budget	4.13	4.10	2.6	2.897	3.928	2.17	3.872	3.75	3.698	3.0	3.209	3.308	4.065	2.506	4.0	4.966	7.724	4.295	3.489	7.320	.443	.580	.55	1.208
2. Labor	.774	.768	.250	.290	.393	.217	.387	.374	.310	.256	.321	.331	.406	.251	.280	.436	.662	.368	.299	.627	.073	.091	.122	.146
3. Cash	3.72	3.69	.390	.724	.982	.543	.968	.935	.924	.450	.802	.827	1.02	.626	1.	1.24	1.93	1.07	.872	1.83	.396	.994	.532	2.
4. Compost	0.	0.	6.	9.5	9.	9.5	11.	14.	4.	7.	11.	12.	10.	5.	6.	14.	15.	11.	8.	13.	-	-	-	-
5. Obj. Function Value	4.13	4.10	2.6	2.897	3.928	2.17	3.872	3.75	3.698	3.0	3.209	3.308	4.065	2.506	4.0	4.966	7.724	4.295	3.489	7.320	-.696	-1.409	-1.225	-3.230

APPENDIX C1

Utilization rates of the available forage (AUYs) by the various animal types from eight land types and the lower limits of the renewable resources.

		O. Cattle[1/]	N. Cattle[2/]	O. Buffalo	N. Buffalo	O. Goat	N. Goat	O. Sheep	RHS Value in LP Formulations	
Amount of forage expected from each land type AUY/animal type	1	-.325	-.357	-.325	-.367	-.325	-.349	-.325	≥	0
	2	-.271	-.298	-.271	-.306	-.271	-.291	-.271	≥	0
	3	-.076	-.083	-.076	-.086	-.076	-.0816	-.076	≥	0
	4	-.022	-.024	-.022	-.0245	-.022	-.0233	-.022	≥	0
	5	-.0028	-.003	-.0028	-.0031	-.0028	-.0039	-.0028	≥	0
	6	-.043	-.048	-.043	-.049	-.043	-.047	-.043	≥	0
	7	-.098	-.107	-.048	-.11	-.098	-.105	-.098	≥	0
	8	-.25	-.274	-.25	-.2815	-.25	-.268	-.25	≥	0
TOTAL AUY		-1.083	-1.191	-1.	-1.224	-1.083	-1.164	-1.083	≥	0

1/ Old, 2/ New.

APPENDIX D

POTENTIAL FOR GROWING FODDER TREES

Currently, over 35 species of fodder trees are being grown in Phewa Tal Watershed area (Shah, 1980). Between 5 - 15 percent of the available forage comes from fodder leaves. The foilage or fruits of these tree species are collected and used for animal fodder mostly in combination with crop residues.

The Food and Agricultural Organization of the United Nations (FAO) lists the following requirements to be fulfilled by good fodder trees:

a. Adoptability - The species should have the ability to establish and maintain itself in the selected environment.

b. Palatability - A fodder species, be it a tree or a shrub, should be readily accepted by animals. Palatability varies from one animal species to another and is influenced by the inter-relationship of plant, animal and environmental factors;

c. Nutritive value - Palatability influences feed intake, but some plants may be low in nutritional value even if their palatability is high. This means that besides palatability and resultant high feed intake, fodder plants should have high levels of various nutrient components of which protein is considered to be the most important. This nutrient is usually recorded as crude protein. *Acacia arabica* pods and leaves contain 15 percent crude protein. Leaves of some other species contain as much as 20 percent of the crude protein. *Albizia lebbeck* and *Prosopsis specifera* are examples.

d. Production and growth - Production of substantial amounts of fodder in the early years after planting is an important economic consideration. In the Near-East and North Africa areas, this requirement was satisfactorily met by using fast-growing and high-yielding drought resistant genera such as Atriplex, opuntia and Acacia.

e. Resistance to utilization - Fodder species can be grazed either directly or indirectly (lopping, cut-and-carry method). The capacity of the species to recover quickly by producing new buds from the browsed and cut stems is important.

f. Not harmful to animals when eaten - Toxicity possibilities should be carefully checked before trees are introduced to provide animal fodder. Based on the above considerations the following potential fodder trees have been identified to grow in Phewa Tal Watershed.

Local Name	Botanical Name	Altitude (m)	Average Fresh Forage Yield kgms/treet
Rato Siris	*Albizzia mollis*	up to 1800	15.0
Badhar	*Arto carpus lakoocha*	1400	105.0
Chiuri	*Bassia butyracae*	1460	18.6
Tanki	*Bauhinia longifolia*	1460	12.8
Koiralo	*Bauhinia variagata*	1460	10.5
Chuletro	*Brassiopsis hainla seem*	2000	56.65
Katus	*Castonopsis* spp.	2400	115.0
Phaledo	*Erythrina variegata*	2000	42.8
Kabhro	*Ficus lacor*	1800	72.8
Bedilo	*Ficus clavata*	1800	195.5
Dudhilo	*Fi cus nemoralis*	2000	68.0
Pakhuri	*Fi cus glaberrina*	2000	148.8
Nimarre	*Fi cus roxburghii*	2000	65.0
Khanem	*Fi cus cunia*	2000	48.7
Kutmero	*Litsea polyantha*	1460	78.9
Chilaune	*Schima Wallichi*	1700	23.5

List of potential fuelwood species for the study area.

S. No.	Botanical Name	Yield m^3/ha*	Growing Location	Other Uses
1.	*Acacia mearasii*	10-25	Above 1000 m	Erosion control
2.	*Ailanthus altissima*	20	0-2000m or more	Erosion control
3.	*Alnus acuminata*	10-15	1,200-3,200m	Erosion control
4.	*Alnus nepalensis*	25-30	1,000-3,000m	Timber Erosion control
5.	*Alnus rubra*	10-11	below 750m	Land reclammation
6.	*Eucalyptus globulus*	10-30	up to 3,000m	Land reclamation Oil & honey
7.	*Eucalyptus grandis*	40	800-2,700m	Paper, Pulp & timber
8.	*Grevillea robusta*	15-20	s.l. - 2,300m	Honey & Shade
9.	*Leucaena leucocephala*	30-40	mainly below 500m	1) Forage 2) Wood 3) Soil improvement 4) Re-forestation

*Rotation of all these species is between 10-15 years.

Source: National Academy of Sciences, 1980. Firewood Crops. Shrub and Tree Species for Energy Production, Washington, D.C.