



Ecology and Agriculture
in
the Himalayan Region

Yasir Saeed Hanafi



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in
the Himalayan Region
Problems and Prospects of Agricultural
Development in North-Western Himalaya



Yasir Saeed Hanafi

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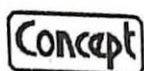
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Foreword

Area Study has assumed considerable significance since the Publication of the monumental reports of the National Commission on Indian Agriculture in 1976. The Commission has drawn special attention to the development of Hill Region.

Dr. Yasir Saeed Hanafi has made a commendable study of the Agricultural Development in North-Western Himalaya in respect of regional inequalities as influenced by agro-ecology. The study becomes very significant owing to the strategic location of the region.

Dr. Hanafi examines in depth the Physical landscape of the area, including the changing land use pattern and forest cover over the last three decades and has clearly brought out that man has interfered in the natural ecological balance. His major contribution which would interest the planners and all those interested in the development of the Himalaya, is his dedicated study of the inequalities in agricultural development and agricultural potential in the region and diversification. In fact there are very few such exhaustive and in-depth study of the Himalaya as Dr. Hanafi has done. Indian and foreigners interested in the Himalaya, I am sure, would like to have a copy of this valuable book.

(Prof. M. Shafi)

Professor Emeritus

population. The urbanization and industrialization at the cost of natural habitats, further results in loss of biodiversity which once lost cannot be recovered. Forest play important role in maintaining ecological balance but ever increasing demand for fuelwood, fodder and timber necessitated by rapid increase in human as well as livestock population, diversion of forest land non-forest uses without ensuring compensatory afforestation and essential environmental safe-guards exerting an ever increasing influence on the environment and ecological balance of the region.

This book on 'Ecology and Agriculture of Himalayan Region: Problems and Prospects of Agricultural Development in North Western Himalaya' tries to present the concept of Agro-ecology and its prospects especially in the Himalayan region. It also tries to present a brief account of constraints of Agro-climatic diversity and man's interventions in this mountainous region. It also presents the possibilities of agriculture diversification and measures of eco-conservation in hilly areas. It is not framed only for the students and scholars of Geography but also helpful for the students of Agriculture, Botany, Biogeography and Environmental studies.

Yasir Saeed Hanafi

Department of Geography
Aligarh Muslim University,
Aligarh (U.P.) India.

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gesture they provide me on every stage of my field surveys and gave me company at every step in the militancy stricken areas of Jammu and Kashmir, otherwise it could not be possible for me to have such a close look of the region, understanding of the various agro-ecological phenomena and observe the actual situation on the spot.

I must not forget the invaluable help of Mr. Rajaneesh Kumar who devoted his precious time in drawing the maps using GIS resource techniques which help me to plot the various features of the region on paper very efficiently.

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Yasir Saeed Hanafi

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1

Introduction

The Problem

In the beginning, man was shaped by the environment which controlled and shaped its evolution and man remained in equilibrium with the environment. But in the quest of its development, man broke this equilibrium and since then he is exerting an ever increasing influence on his environment. Due to growing urbanization and industrialization, man distorted its environment.

All developmental activities, irrespective of their scale nature and magnitude affect the environment. The impact of their developmental activities may have short-term as well as long-term implications. The short-term implications may be negligible as compared to the benefits of the developmental programmes but the long-term implications may further create new ecological and environmental problems, the solutions for which may not be easy to find. Some of these implications may be summarized in terms of vast areas of deforested lands, denudation of slopes, soil erosion and silting of rivers, regular occurrence of floods and droughts, impoverishment of important flora and fauna, changed climate, polluted water unfit to drink and contaminated air unfit to breath.

The ecological balance of flora, fauna and forests is being drastically disturbed by the rapid increase in human

population. The urbanization and industrialization costs the decrease of natural habitats, which further results in loss of biological diversity. Biodiversity, once lost cannot be recovered. Forests play an important ecological role, the serious depletion of which attributed to a number of factors. These include the ever increasing demand for fuel-wood, fodder and timber necessitated by rapid increase in human as well as livestock population, diversion of forest land to non-forest uses without ensuring compensatory afforestation and essential environmental safeguards.

Besides these, land degradation is a major problem which results in loss of its intrinsic qualities or a decline in its potential utilities and capabilities. Land degradation may be caused due to natural or human factor or due to the combination of both. Soil erosion by rain and river that takes place in hilly areas causes landslides and floods, while cutting trees for firewood, agricultural implements and timber grazing by large number of livestock over and above the carrying capacity of grasslands, traditional agricultural policies. Soil erosion results in huge loss of nutrients in suspension or solution, which we removed from one place to another, causing depletion or enrichment of nutrients. Besides the loss of nutrients from topsoil, there is also degradation through the creation of gullies and ravines which makes the land unsuitable for agricultural production.

The process of agricultural resource of development has a large and long-term impact on the natural component of a region through the destruction of original ecosystem. The unscientific and irrational agricultural transformation process now operating in the ecologically fragile Himalayan region, in terms of the extension of cultivation to up slope, marginal and sub-marginal lands, clearing of forest areas under the increasing pressure of population and changing pattern of agricultural landuse and cropping has introduced a variety of new conditions to the traditional agro-ecology of the region.

Increasing population concentration in this mountainous tract deserves specific and adequate attention for protecting the environment and sustainable development of natural resources because the fragile ecosystems of these mountainous region are vulnerable to all kinds of anthropogenic interferences.

During recent years, the growth of population and technological development tends to affect adversely the ecology both by utilizing the environmental resources beyond the carrying capacity of the nature and by altering the resource use pattern. The scarce agricultural resources of the region are now under great biotic stress. More than 70 per cent of the population of the region is solely dependent on agriculture which is being practiced in most compelling circumstances in almost complete absence of other means of livelihood in the majority of the areas. The land use pattern of the region has been undergoing a process of rapid change and transformation with more and more areas come under wasteland, pastures and cultivation. This process of irrational utilization of natural resources has not only depleted and degraded the critical environmental components in this ecologically sensitive and economically underdeveloped mountainous tract but also threatened the agro-ecology of the region itself.

Presently, the agro-ecology of this region is threatened by two-fold human interactions. First, the quest to increase the area under cultivation and second to get maximum possible agricultural return from a unit area. This in turn has given rise to three main problems of agro-ecological nature in the region. First, for agricultural operation, the clearance of forest areas is badly affecting agro-ecological balance. Consequently, the cultivation is now pushed to forest areas, marginal lands and up slopes without making into account the suitability of these lands for agriculture and vegetal cover is being lopped and cleared for fuel and fodder

and finally the patches are being brought under grazing. This unscientific and irrational land transformation process has brought about very serious environmental crises in terms of erosion of top soils and reduction in groundwater recharge in this ecologically sensitive region. The process and magnitude of soil erosion is a function of a number of factors operating in combination such as intensity of rainfall, amount of surface run-off and infiltration, chemical and physical properties of rocks, gradient of slope, drainage density and of course the process of land transformation followed by man.

In the Himalayan agro-ecological region, erodibility of land by overland flow depends on the degree of slope and its length. There will be no erosion until the depth of water and slope acquire an erosion force. The process of soil erosion is intensified by the volume of water accumulating on a long slope and the consequent increased velocity of run-off (Bennet, 1955). It has been proved experimentally that if the degree of slopes is doubled the erosion per unit area increases two and a half times and on an average soil erosion increases one and a half time per unit area when the length of the slope doubled (Khonke and Bertrand, 1959). Surface run-off in another factor of soil erosion, lesser will be the rate of infiltration and permeability, the more will be the rate of overland flow and greater will be the volume of surface run-off and ultimately the higher will be the magnitude of soil erosion.

Second, to get maximum return from agricultural land, heavy doses of fertilizers, insecticides, pesticides and irrigation are being applied without any proper knowledge of actual requirement of the agricultural land. This has resulted in the problems like development of toxic soils, elimination of favourable pest and insects, toxicated water flow in the out drainage river channels, multiplication of pesticide-resistant pests, concentration of harmful salts in the agricultural fields, waterlogging, salinity and alkalinity etc.

Thirdly, good quality agricultural land is being brought under non-agricultural uses, like roads, buildings and water channels, etc. because of the increase of the urbanization.

In the Himalayan mountain geosystem about 60 per cent of the total geographical area should be under permanent vegetal cover keeping in view the smooth functioning of geo-eco-cycle. Against this ecological standard, forest cover in north-western Himalaya as a whole confined to only about 44.67 per cent during 1992-95. Large scale transformation of forested sites was carried out to meet the ever increasing demand for agricultural land and pastures due to rapidly increasing human and cattle population. This phenomenon pushed the uneconomic agriculture (high input and low output) in marginal lands, steep slopes, forested sites and even on other categories of land which is not suitable for this purpose. This human transformation process has resulted into cleared forests and terraced slopes, damaging the entire forest ecology. More than two-third of the total population of the region depends on agriculture for its livelihood and in this agricultural economy cattle are very closely interrelated with crop farming. Cattle are the only medium of energy transfer and energy input (in terms of manuring soils and labour) to the Himalayan agro-ecology.

Hence, it is required to maintain relatively higher cattle population to meet the increasing demand of manure and labour for agricultural expansion. In the recent years, the pressure of grazing animals has increased far beyond the carrying capacity of pastures and forests in the region. It has been estimated that only 0.13 to 0.30 hectares per cattle grazing land is available against the ecologically recommended standard of minimum 6 hectares per cattle in the Himalayan ecological region. (Ashish, 1983).

Concept and Definition

Nature in its diverse ecological conditions offers its diverse earth units with completely different possibilities of

utilization.¹ It not only imposes limits but also indicates the direction of specialization. Thus efforts are needed to investigate the agro-ecology of a region to meet the ever growing human need in harmony with the ecological balance. Agro-ecology is a twin word 'Agro' means related to agriculture and agriculture is come from the Latin term 'agercultura' which consists of two words, namely, 'ager' meaning field and 'cultura' meaning to cultivate. Agriculture is defined by different scientists in different words such as "use of human efforts with the object of inquiring product of plants or animal origin" (Whittlesey, 1936), "Man's husbandry of land" (Symon, 1967), "the practice of cultivation of soil in order to produce crops is called agriculture" (Grigg, 1969), "a way of living as well as an occupation" (Gregor, 1970). In *Encyclopaedia Britannica*, agriculture is the science or art of cultivating the soil, growing and harvesting the crops and livestock.

The term 'ecology' seems to have almost as many meanings as there are ecologist. Ecology is one of the three major divisions of biology, the other two being morphology and physiology. The emphasis in morphology is on how organisms are made?, in physiology how they function? and in ecology how they live? Ecology, is a very simple term, a science that studies the interdependent, mutually reactive and interconnected relationships between the organism and environment on the one hand and among the organisms on the other hand. In 1959, Geoffrey Saint Hillaire used the term 'ethology' to refer to the study of relationships between the organism and the environment, but the term was never generally accepted by the earlier ecologists. Later ethology has been considered as an important part of ecology dealing with the field of animal behaviour. Nine year later, Reiter introduced the 'oekologie' derived from two Greek words 'Oikos' meaning 'home or house or household or something like that' and Logos meaning a 'discussion or study.' Ernst Haeckel had falsely credited with the derivation of the term

because he defined it in the literature a year later. The term has since been anglicized to ecology (C.B. Knight, 1965, p. 8). Since then its published definitions now range from traditional study of the relationships between organism and their environment (Hughes and Walker, 1965), to the embracing structure and function of nature (Odum, 1963), which virtually identifies it with the whole of natural science.

Ecology, to great extent concerned with the habitat, and it, cosequently, applied habitat biology. Elton (1949), succinctly defined the habitat as an area possessing uniformity of physiography, vegetation, climate or any other quality the investigator assumes is important. Habitat, though they are restricted in an area will exhibit considerable variability in size from a coniferous forest or oceanic area measured in terms of hundred of square miles to an exposed surface of rock or the lower surface of a twig a few square centimeters or a fraction of square millimeter in area. The later two examples are called micro-habitat by most ecologists (Knight, 1965, Basic concept of Ecology, p. 3).

Habitat refers to the sum total of all external conditions affecting the development, special response and growth of plants (organisms). Since the term habitat was first used by botanists, and especially by ecologists, it is best to apply it to the description of the physiological conditions influencing the distribution and growth of plants as contrasted with social environment which deals with the influence of a variety of factors other than those concerned with the direct growth requirements determining the distribution of crop plants² (Klages, 1942). In the words of Paul, A. Colinvaux (1973), ecology is invented to convey the idea of the study of animals and plants in relation to their habits and habitats.³ Stability and unstability of an agro-ecological region can be understood from the following concepts of ecology. According to Jordan (1975), an adequate definition of ecology must specify the unit of study that is unique or basic to ecology and such a basic unit obviously is the '*ecosystem*.' This term was

first proposed by British ecologist A.G. Tansley in 1935. Thus, ecology may be defined as "the study of ecosystem" (Kumar, 1975). An ecosystem in turn is an integrated unit, consisting of interacting plants and animals whose survival depends upon the maintenance of abiotic as well as biotic structures and functions. The basic and most important concept of an ecosystem is that everything is somehow or the other related to another thing else, and such relationships include interlocking functioning of organisms among themselves as well as with their environment. Smith (1966), has emphasized the following general characteristics of most ecosystems:

- ❖ The ecosystem is a major structural and functional unit of ecology.
- ❖ The structure of an ecosystem is related to its species diversity, the more complex ecosystem have high species diversity.
- ❖ The function of the ecosystem is related to energy flow and material cycling through and within the system.
- ❖ The relative amount of energy needed to maintain an ecosystem depends on its structure. The more complex the structure is, the lesser the energy it needs to maintain itself.
- ❖ Ecosystem matures by passing from less complex to more complex states. Early stages of such succession have an excess of potential energy and a relatively high energy flow per unit biomass. Later (mature) stages have less energy accumulation and its flow through more diverse components.
- ❖ Both the environment and the energy fixation in any given ecosystem are limited and cannot be exceeded without causing serious undesirable effects.
- ❖ Alteration in the environments represent selective pressures upon the population to which it must

adjust. Organisms which are unable to adjust themselves under changed environmental conditions does not survive and becomes extinct or vanishes from the Environment.

Ecology is one of the most popular branch of biology and differs from most other branches of biology is that it can be properly appreciated or studied only through a multi-disciplinary approach involving close cooperation from experts in several disciplines e.g., physics, geography, engineering, mathematics, statistics, zoology, botany, microbiology, limnology and chemistry. In fact most of our present-day environmental problems have been caused by the lack of appreciation of the multidisciplinary perspective and through a narrow perception of the world (Kumar, 1977, p. 1). The term ecology is now widely used in the field of social, as well as biological science, whilst the subject of ecology covering as it does the relationship of the organism to its environment, has many facets (Southwood, 1978).

The definition of ecology stated above is, however, not accepted universally. In certain countries, e.g., the U.S.A., Canada and England, 'ecology' includes within its scope both the description of communities and the more experimental ecological investigations, e.g., energetics. On the other hand in European Continent, the term 'ecology' (also sometimes called eco-physiology) is restricted to the experimental part only whereas the descriptive part is styled as sociology e.g., plant sociology or animal sociology. The chief objective of an experimental ecologist or eco-physiologist is to understand the mass and energy turnover within different ecosystems and to estimate quantitatively the primary and secondary production. (Kumar, 1977, p. 3).

Barret (1978), advocates restriction of the term ecology to define that discipline which attempts to understand the structure and function of ecosystems, whereas 'environmental sciences' be defined as an interdisciplinary science

which attempts to study the impact of man on the structure and function of social and ecological systems as well as management of these systems for human survival and benefits. One should have to know the following three concepts of ecosystems to understand the agro-ecology of a region in a sound manner:

(a) *The Concept of Climax*

The climax concept has long been and indeed still is, central to many ecological principles. The climax is the final or it is sometimes described the nature stage or end point of ecosystem biomass possible, under prevailing environmental conditions, has been attained. The ecosystem reached a steady state which implies a relative balance or equilibrium in respect of its biomass, species populations, inputs of energy and nutrients and biological productivity.

(b) *The Concept of Stability*

One of the most important attributes of the climax or mature ecosystem, is that of stability. This is the ability of a system to maintain a relatively constant condition in terms of its species composition, biomass and productivity, with minor fluctuations around a mean value (the equilibrium point) and to return to this steady condition fairly rapidly after interval or external disturbances.

(c) *The Concept of Fragility*

Another important characteristic of ecosystem related to stability is that of fragility, this is an ease with which an ecosystem can be disrupted. It will depend, first on the relative resilience of the system and second on the type of disturbance to which it is subjected.

Resilience is the term used to describe the ability of an ecosystem to persist and to maintain itself in the face of disturbances due to weather or climate, chemical factors, organisms or human. The relative resilience of an ecosystem depends on:

- (a) Its amplitude or how far it can deviate from the equilibrium or steady state (before complete disruption and replacement by another system occurs).
- (b) Its elasticity or the rate with which it can recover from disturbances. Fragility will obviously vary from one ecosystem to another.

Fragility also depends upon the type of disturbance, in terms of intensity and duration of which the ecosystem is subjected.

It is evident that the concept of agriculture and ecology, should be clear from the foregoing discussion. Ecology with some prefixes modifies its definition e.g., Human ecology is the study of man's relation to environment, especially man's effects on the biosphere and implications of these effects for man. Population ecology is the study of the progress that affect the distribution and abundance of animal and plant populations. The concept of agro-ecology began in 1930, when Bensen proposed the term agro-ecology to apply for 'the detailed studies of commercially important crop plants by the use of ecological methods.' He proposed a systematic collection of data so that the main agricultural regions (agrochoras) of the world and the characteristics of local cultivated varieties of important crops (chorotypes) may be described and recorded by the employment of standardized methods and by a prescribed and uniform terminology.⁴ The agro-ecology is defined as 'the study of the physical characteristics of environment, climate and soil, in relation to the development of agricultural plants, and to the yield of such plants from the quantitative (amount of the product),

qualitative (quality of the product), and generative (characters of the seeds) point of view' (Azzi, 1956)⁵. Recent concept of agro-ecology is 'the study of optimization of agricultural production with least deterioration of natural resources and environment.' Crops like other plants have distinct ecological preferences of altitude, climate, soil, photo-period at different stages of life cycle, but they can usually be grown over a wide range of environments. Man can often modify the environment by cultural and other methods to provide better conditions for growth and productivity.

Significance of the Study

The north-western Himalaya because of the increasing population concentration deserves specific and adequate attention for protecting the environment and sustainable development of natural resources. The fragile ecosystems of this mountainous agro-ecological region are vulnerable to all kinds of anthropogenic interference. The extensive soil erosion, frequent landslides because of deforestation, extension of cultivation, overgrazing and construction activities.

The study of this region has become more significant in recent years with massive growth in population and the scarce agricultural resources of the region are now under great biotic stress. More than 70 per cent of the population of the region solely depends on agriculture which is being practiced in most compelling circumstances in the almost complete absence of other means of livelihood in the majority of the area. The land use pattern of the region has been undergoing a process of rapid change and transformation with more and more area under wasteland, pastures and cultivation. This present process of irrational utilization of natural resources has not only depleted and degraded the critical environ-mental components in this ecologically sensitive and economically viable mountainous tract but

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also threatened the agro-ecology of the region in a worst manner.

This study also has its significance for the agro-ecological development of the region because it assess and correlate various parameters like land capability, temperature, rainfall, relief, geohydrological balance, rate of soil erosion, extent of deforestation, magnitude of surface and subsurface water pollution because of suggested biochemical techniques, population structure and existing pattern of agricultural resources utilization.

Significance of the present study also become evident as agro-ecology studies the agro-ecosystem in the biosphere. Agro-ecosystems⁶, studies mainly under 'production and conservation ecology.' In production ecology such parameters are studied that increase the agricultural production, while in conservation ecology, such parameters are studied that explain the basic prerequisite components of agriculture. Agro-ecological study of the region become inevitable as crops like other organisms have distinct ecological preferences of altitude, climate, soil, photo-period and micro-nutriets at different stages of their life cycles, a few examples of such preferences are cited here for deficient, optimum and toxic responses of crops.

A very clear relationship of temperature with yield of spring wheat were plotted on a graph (Fig. 1.1) bearing the yield expressed in quintal per hectares and temperature in °C, taken from the work of Girolamo Azzi. The curve which geometrically co-ordinates all the points on the graph are the true representation of yield's course in respect of temperature. This curve may be divided into three parts, a central and practically horizontal part comprising wheat we may call the favourable situation or optimum response and two laterals in rapid decline corresponding to unfavourable situations through the excess and deficiency.

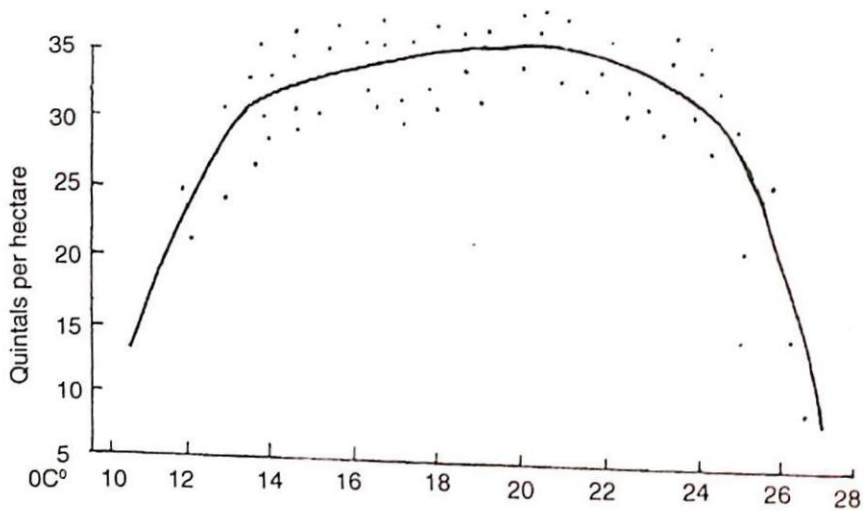


Fig. 1.1 : Yield of spring wheat in relation to temperature

Another example which highlights the response of duration of temperature on development of root drawn by Talma and cited by Klages. The effect of the length of the exposure to given temperatures on the development of root in *Lepidium sativum* can be seen very clear in Fig. 1.2. The temperature for optimum rate of development in the root system of *Lepidium sativum* are different for different period of exposures. A short exposure of three and half hours, showed optimum development at 30°C, with doubling of time period i.e., 7 hours, the optimum temperature for development in root system is found at 29°C, and when the period of exposure lengthened to 14 hours, the highest rate of activity was at 27.2°C. It is noted that, the increase in temperature, especially with the longer periods of exposure, exerts influence depressing to growth. The growth depressing to factors become more and more active with the approach of the optimum and beyond it account for the rapid downward trend of the growth curves.

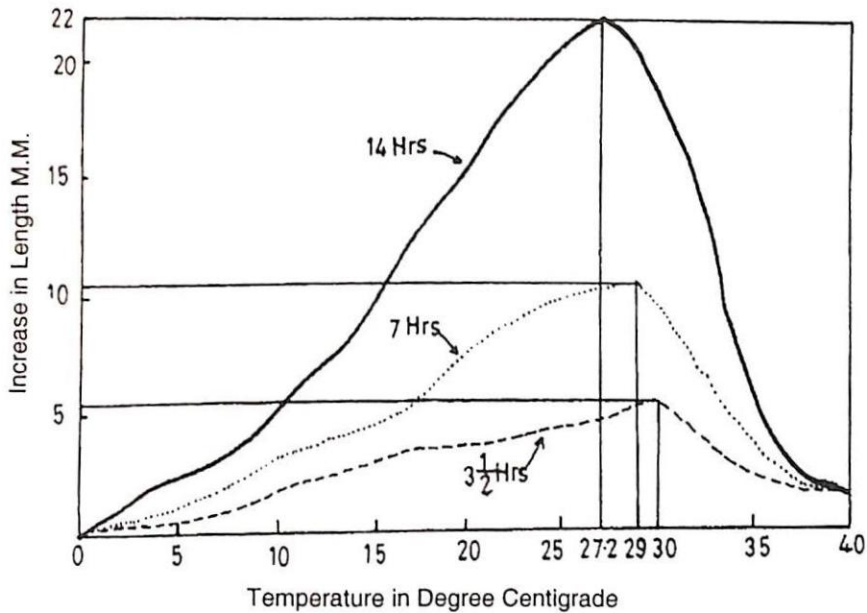


Fig. 1.2 : Effect of length of Exposure of Temperature on the Root length of *Lepidium sativum*

Aims and Objectives

In order to check the agro-ecological threats from becoming unmanageable problems in the region, the eco-conservation and sustainable eco-friendly economic activities becomes inevitable. As a result of urgent and dual problem of conservation and increase in production, agricultural research in the last decade has tended to move from 'maximization of production' towards 'optimal use of agro-eco-system.'⁷ This approach has been more beneficial in the developing countries, where it has ensured enhancement of productivity without disbalancing much of the ecological setup for agricultural activities.⁸

It is, therefore, imperative to integrate agricultural development policies with environmental management and planning in ecologically sensitive Himalayan tract. The agro-

ecological planning in this context is referred to as scientific and integrated framework for ecologically sustainable and economically viable development of agriculture through ensuring optimum and most rational utilization of environmental resources. Agro-ecological development need information on various parameters like land capability, temperature, rainfall, relief, geohydrological balance, rate of soil erosion, extent of deforestation, extension of farming, magnitude of surface and subsurface water pollution because of suggested biochemical techniques, population structure and existing pattern of agricultural resource utilization.

Keeping in mind the above aims, the basic objectives of the present study are:

- (i) To identify the agro-ecological parameters and technoeconomic factors for inequalities in agricultural development of the region.
- (ii) To study the changing land use pattern and its impacts on the agriculture and ecology of the region.
- (iii) To study the changing cropping pattern and its impact on ecology of the region.
- (iv) To identify the driving forces for deteriorating agro-ecological scenario of the region.
- (v) To identify the suitable ecological region of specific crops.
- (vi) To identify the potential agricultural region for planning purposes on priority basis.

Database

The problems facing in the data collection during the entire work piece of work are of different nature, such as to take the complete geomorphic unit of north western Himalaya as the study region become too large and come under the

administrative limits of three different state which further sets problems like the point or period which I choose for data analysis, not necessarily tally in the records of all three states because they record and publish data according to their convenience. The frontier of this region is surrounded by Pakistan, Afghanistan, China and Nepal. So a large number of information and materials of the region are either restricted or censored for political reasons, besides it a large portion of the region is a matter of conflict with the neighbouring countries and to get the exact information and real situation of such areas is a difficult task. Militancy in the region further sets hurdles for the research work.

Considering the above problems of the area, the data has been collected from the following secondary sources:

- (a) The data of area production and yield of principle crops has been collected from the Director of Economics and Statistics, New Delhi; Director of Economics and Statistics, Srinagar; Financial Commissioner's office, Tankipora, Srinagar; Directorate of Economics and Statistics, Shimla and Lucknow.
- (b) Meteorological data has been collected from the Indian Meteorological Department, Lodhi Road, New Delhi. Also from the statistical abstracts of Himachal Pradesh, Jammu and Kashmir and Uttar Pradesh.
- (c) Livestock and agricultural machinery data has been collected from Livestock Censuses, Directorate of Economics and Statistics, New Delhi.
- (d) Data of soils has been collected from various reports of Director, Soil and Landuse Survey, IARI, New Delhi.
- (e) Water resource data has been collected from Water Commission of India, New Delhi.

- (f) Data of Landuse Statistics has also been collected from the Directorate of Economic and Statistics, New Delhi, Lucknow, Shimla and Srinagar.
- (g) Water Resource Development Atlas of India and National Atlas of India have also been used in final plotting and verifications of various data.

Methodology

The study has been conducted on the basis of secondary sources of data and their verification by personal surveys at micro-level. Since, the region is too large the *district has been taken as the unit of study*. There are 34 districts in the region. 14 in Jammu and Kashmir, 12 in Himachal Pradesh and 8 mountainous districts of Uttar Pradesh Himalaya now known as Uttaranchal.

During the period of 1950s till now, there were formed several new districts from the existed ones. As a result, the up to date data of all the districts is not possible, in such cases generally the data of newly formed districts has clubbed for convenience but here only those districts are taken into consideration which are given in 1991 Census of India. Out of these 34 districts, only those districts are taken for data analysis which have been existing since 1950s and their data is also available for all point of time.

Decadal growth in agricultural development of various parameters has been calculated by simple growth rate formula:

$$R = \{(b/a) \times 100\} - 100$$

where,

b = any value of later date

a = any value of previous date

The trend of agricultural development has been calculated by the logarithmic trend line equation which is given below:

$$\text{Log } Y_t = \text{Log } a + x \text{ Log } b$$

$$\text{where } \text{log } a = \sum (\text{log } Y) / n$$

$$\text{Log } b = \sum (x \text{ log } Y) / \sum x^2$$

The trend line values have been plotted on the smooth line curve to show the actual situation of the trend. To determine the rate of change following equation has been used:

$$r = R - 1$$

where, r is the rate of change

R is the antilog of $\text{log } b$

Finally, the collected data of various agricultural parameters has been standardized by using standard score (Z-score) method. On that basis composite development index has been developed to find out the inequalities in agricultural development of the region.

Organization of the Study

The present thesis has been divided into seven chapters. The *first chapter* is the introductory chapter highlights the statement of the problem, the concept of Agro-ecology and significance of the study besides the traditional background items. *Second chapter* deals with the agro-ecological components of the region, significance of prevailing climatic constraints in agricultural practices. Also agro-ecological consequences of the changing landuse pattern and livestock pressure analysed in this chapter. The emphasis of the *Third chapter* is on the understanding of natural ecological balance,

ecological parameters in the light of ecological laws, ecological requirement of different crops and how the agricultural practices responded to different ecological parameters. *Fourth chapter* analyzes the trend of agricultural development in terms of agricultural inputs and agricultural development in the region and also to record the possibilities and potentials of agricultural development in the region. *Sixth chapter* focuses on conservation of ecology and sustainable agricultural development as well as integrated approaches of sustainable agricultural development. The *seventh chapter* conclude the investigations and findings of the thesis.

Location and Extent of the Region

North-western Himalaya, as delineated in this study covers an area of about 3,29,032 sq. kms, lying within the Himalayan system west of river Kali that separate Pithoragarh district of Uttaranchal (India) from the Kingdom of Nepal. This region is a complete geomorphic unit and well distinct agro-ecological or agro-climatic region different in all its physio-cultural and socio-economic conditions. This region extending over about eight and half degrees of longitude, the western most point of this region lies just west of Chunar Khan pass on $72^{\circ}40'$ of east longitude while its eastern most point lies on the north-eastern tip of Pithoragarh district which is about 50 km. West of Mangsha Dhura pass on $81^{\circ}02'22''$ of East longitude, occupying almost one-third of the total East-West extent of the Himalaya. The northern and southern limits of the region stretching over eight degrees of latitude. The northern most point of the region is lying between Kilik Dawan and Khunjerab pass on $37^{\circ}05'$ of north latitude while southern most point lies about 50 km. South of Tanakpur on south-eastern corner of Nainital on $28^{\circ}43'24''$ of north latitude.

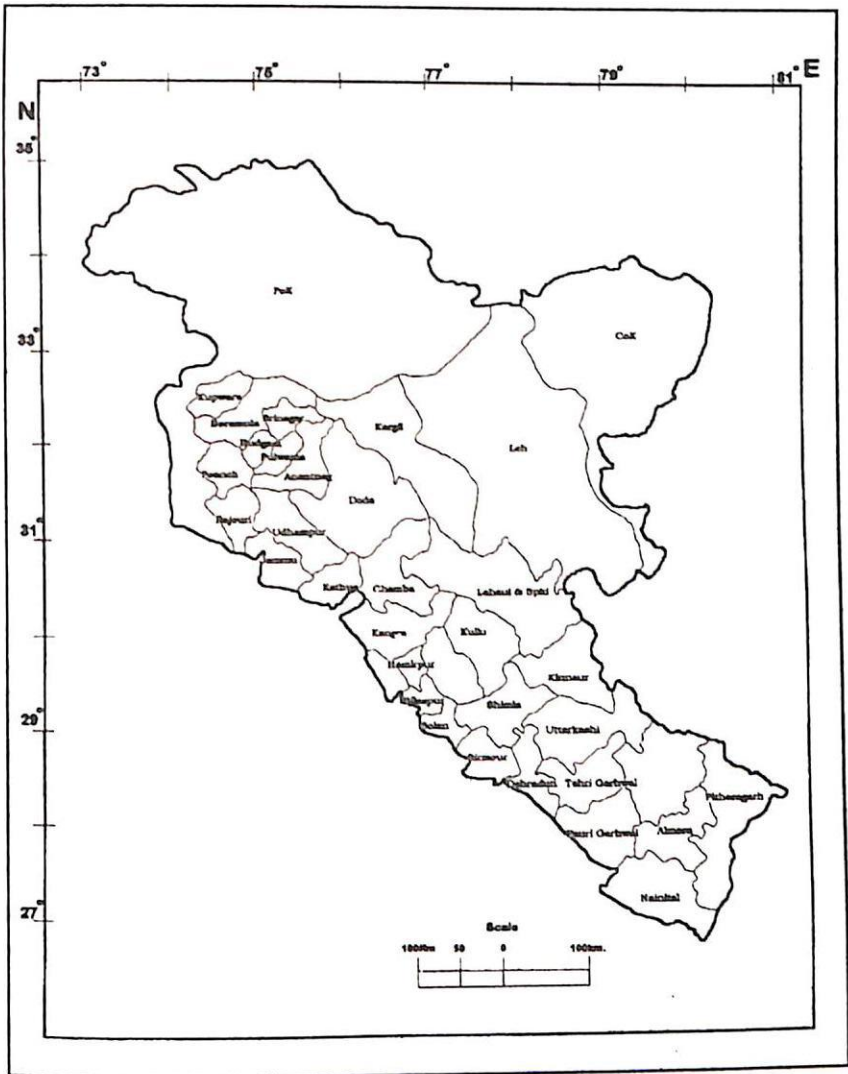


Fig. 1.3 : North-western Himalaya : Administrative Setup

North-western Himalaya is a single geomorphic region but this region comes under the administrative limits of three northern states of India. A major western portion lies within Jammu and Kashmir, occupying an area of 2,22,236 sq. kms. or 67.5 per cent of the total area of this geomorphic region, another 17 per cent or 55,673 sq. kms. of area of mountains comes under the administrative powers of Himachal

Pradesh, while the remaining 15.5 per cent constituting an area of 51,123 sq. kms. is the northern portion of Uttar Pradesh and now come under the administrative limits of newly formed Uttaranchal state with two exceptions as Saharanpur is not included in it because of its plain nature while Nainital included in totality including plain area of Udham Singh Nagar for the convenience of secondary data availability and analysis.

North-western Himalaya, is by far, the most curious among the three main east-west sections of the Himalayan chain and also occupying a commanding and crucial situation within the entire mountain chain with elevation more than 7000 meters, this majestic crown of Hindukush Himalaya is a complex area both geologically and geographically. It has a unique significance in the relief and hydrology of the entire subcontinent and constitutes the orographic and hydrographic focus of the entire landmass. Besides the vast glaciated zone and a large number of perpetually snow covered peaks along the Karakoram crest zone and the greater Himalayan chain to the south and southeast, the region account for the second highest peak of the Himalayan i.e., mt. K₂ (8611 m). The Karakoram ranges and the entire zone of perpetual snow right from Nanga Parbat (8126 m) in the north-west to the Nanda Devi (7817 m) in the south-east abounds in glaciers of varying sizes, many of which are giant streams of ice exceeding 30 km in length. Some longest glaciers of the world are also found here like Siachen with 72 km. and Biafo with 62 km of lengths. According to an estimate, about 16,000 sq. kms. area of Karakoram and 9500 sq. kms. area in Greater Himalayan ranges in the north-western Himalaya is under glaciated ice.

The region as a whole dominated by several giant and smaller parallel mountain ranges running north-west to south-east like Siwalik ranges in the extreme south with elevation ranges between 450 to 950 m, parallel to it is Dholadhar range with elevation more than 2000 m. Above

this Dholadhar range which is significant only in Himachal Pradesh east of Ravi, the Pir Punjal ranges starting from the north of Muzaffarabad in the north-west up to Manali in Kullu district of H.P., a continuous chain with an elevation ranges between 4000 m and 5000 m. The range parallel to it in the north is the Great Himalayan ranges running to the full length of north-west Himalaya right from Indus near Chilas in the extreme north-west up to the Pithoragarh near Nanda Devi to a length of about 1000 kms. and its elevation is generally found more than 5000 m above mean sea level. The Zaskar range north of it runs parallel from Wakha sector of Kargil district in north-west up to the northern boundary of Pithoragarh with China in the south-east with an elevation of about 6000 m. and the Ladakh range found north-east of it with an average elevation more than 6000 m. In the extreme north Great Karakoram ranges with number of snow clad peaks and Glaciers like Hispar, Biafo, Balono and Siachen Glaciers with few peaks of more than 7500 m occur in these ranges.

Between these parallel ranges there are considerable but widely distributed stretches of wide and fertile valleys throughout the length and breadth of the region like Kashmir valley, Kullu valley, Dun Valley, etc. Their evolution being associated with a variety of causes e.g. some of these valleys are the result of fluvial action i.e., vertical and lateral erosion by rivers, it is evident that these have been vast lacustrine areas in the past.

The most important among them, is the Kashmir valley, which is an oval 'dun' of tectonic origin. The valley is about 135 kms. long and 14 kms. wide, thus encompassing a total area of 15,853 sq. kms. It is 200 kms. long and 125 kms. wide when aerial distances are measured from crest to crest. The mean elevation of the valley of Kashmir is 1830 m with heavy concentration of human activities between 1510 m and 1800 m. The valley is surrounded by the Great Himalaya (Himadri) and the Pir Punjal range with 12 passes. Banihal pass (2832 m), Zoji la (3529 m), Deosai pass (3765 m), Burzil pass (4199

m), Kamri pass, Babusar pass (4173 m), Janod, Kepan, Tithwal, Hajipur, Baramula and Pir Punjal Pass. Dehradun is the biggest and most developed dune of the Uttaranchal. It is about 35 km long and 25 km. wide. It rises from 360 m along the Yamuna and Ganga to 660 m in the middle and 900 m near the foothills.

The north-western Himalayan region occupies an strategic position in South Asia with its border touching Pakistan in the west, China in the north, Tibet in the east and Nepal in the south-east. The valley of Ab-i-Panja in Afghanistan separates India from Tajikistan.

It is over the majestic heights of its snow-capped mountains that several passes providing route link with adjacent countries. Notable among them are Babusar pass in Chilas, Burzil pass in Gilgit, Karakoram pass (5575 m) in the north Ladakh while Lanak La pass (5486 m) in eastern Ladakh are of utmost importance.

The north-western portion of Kashmir has more massive mountains and within a radius of 112 km of Gilgit town, there are 21 peaks over 6000 m with Nanga Parbat at the Highest with 8126 m. The north-eastern portion of Ladakh has an average elevation over 6000 m, where Mt. K₂ or Mt. Godwin Austin (8611 m) on Karakoram range is the second highest peak of the world.

In north-western Himalaya, the region lies south of Kashmir is Himachal Pradesh with intricate mosaic of mountain ranges, hills and valleys. The Dhauladhar range looks in supreme majesty over the Kangra Valley, while Pir Punjal, Great Himalaya and Zaskar ranges looks over Chamba, Lahaul Spiti, Kullu and Kinnaur. There is general increase in elevation from west to east and south to north. The Great Himalayan range (5000 m-6000 m) runs along the eastern boundary with certain passes, such as Kangla (5248 m), Bara Lacha la (4512 m), Kanzam (4551 m), Parang (5548 m) and Pin Parbati (4802 m) while Zaskar range is the eastern most

range with peaks over 6500 m, like Riwo Phargyul (6791 m) and Shilla (7026 m).

To the south-east of it, lies the U.P. Hill ranges or Uttarakhand region, consists of snow capped glacier peaks like Bandar Punch (6315 m), Gangotri (6614 m), Kedarnath (6940 m), Chaukhamba (7138 m), Kamet (7756 m), Nanda Devi (7817 m), Dunagiri (7066 m), Trisul (7120 m) and Nandakot (6861 m).

Review of the Work done So Far

Agro-ecology, 'the study of physical characteristics of environment, climate and soil in relation to the optimum agricultural production with least deterioration' is a discipline which is not recognized all of a sudden but its roots goes to the writings of early Greek philosophers. Aristotle classified animals according to their habits and habitats, but he didn't consider the interrelations of plants, animals and their environment.⁹ It was however, Theophrastus, an associate and student of Aristotle who in 4th century B.C. first described the interrelations between organisms and their environment. He is therefore referred as first ecologist.¹⁰ The population regulation of insects-pests has long been under study e.g. the introduction of Mynah bird from India to the Islands of Mauritius in 1962 reduced the red locust threat to a negligible problem by 1770.¹¹ Similarly, the introduction of predatory ants from nearby mountains into date palm orchards to control other species of ants in south-western Arabia has been mentioned in the writings of Forskal in 1775.¹² The 18th century botanist Richard Bradley understood the basic similarities between animals and plants production, and proposed the methods of obtaining maximum agricultural yields for trees, vineyards, rabbits, poultry and fish.¹³

A botanist Justin Liebig, in 1840, stated that any

environmental factor that most closely approached the critical minimum for a species will tend to be a limiting factor for that species.¹⁴ Liebig's idea has since been incorporated into the ecological literature and called the 'Law of Minimum.'

Zones of the flanks of high mountains became of particular interest to ecology as a result of the work in Arizona by one man C. Hart Merriam. He was charged with a biological survey of part in Arizona in 1889, in the pioneer days when the region was still biologically unknown. He was particularly impressed with the vegetation belts he encountered on the ascent of the 13,000 feet San Francisco Mountain.¹⁵

Investigation during the beginning of 20th century have set ecology and ecological relationships more and more on a specific and on experimental basis. In 1903, Davenport¹⁶, published a paper on the animal ecology of Coldspring Harbor while in 1907, Forbes, wrote about the distribution of Illinois fishes.¹⁷ E. Warming (1909), a Danish plant ecologist, recognized the interdependence and close relationships that often exists between plant and animal communities and cautiously recommended dealing with plant and animal communities an entity rather than separately.¹⁸

On the question of limiting factors, a very considerable literature has developed, and numerous theories have been advanced, since the appearance of Blackman's initial paper in 1905. Blackman's axiom of limiting factor is in reality an elaboration of Liebig's law of minimum which in its essence may be as "the yield of any crop always depends on that nutrient constituent which is present in the minimum amount."¹⁹ V.L. Shelford in 1913, expanded Liebig's observations to include the maximum limits of an environmental factor. Thus 'Shelford law of tolerance' states that "a value below a critical minimum or a quantity or factor in excess of the critical maximum would exclude certain organisms from environmental areas."²⁰

The branch of science known as Agricultural Ecology, first mentioned in a report presented to the "Accademia dei Lincei" by a commission of inquiry composed of Messrs. L. Luzzatti, L. De Marchi and R. Pirotta; on the scientific activities of Prof. Girolamo Azzi in 1920. The commission has reported that, "this branch of science (Ecology), has a purely scientific character and scope, that it considers the plant as an organism thriving in its environment, and it can have great practical significance when dealing with plants cultivated by man for his own requirements, it then becomes agricultural ecology."²¹ Following this report in 1921, the Ministry of Agriculture has created a chair in agricultural ecology, the first in the world at the Institute of Superiore Agrario, Perugia.

The study of agricultural ecology has been started from 1929 when Girolamo Azzi went to establish for the first time a course in this subject at the faculty of agriculture, University of Buenos Aires, Argentina.²²

Tansley in 1926, used the term in its widest meaning as the study of organisms as they exist in their natural homes, or as the economy, household affairs of organisms.²³ Weavers and Clements in 1929, stated that "every plant is a product of the conditions under which it grows." It indicates in general and often in a specific manner what other species would do if grown in the same place.

The term 'Agro-ecology' for the first time proposed by B.M. Bensen in 1930, to apply for the detailed studies of commercially important crop plants by the use of ecological methods.²⁴ He proposed a systematic collection of data so that the main agricultural regions (agrochoras) of the world and the characteristics of local cultivated varieties of important crops (chorotypes) may be described and recorded by the employment of standardized methods and by a prescribed and uniform terminology. It is observed that Bensen dealt only with commercially important crops so a

large number of other crops excluded from the field of agro-ecology.

One of the classic works 'Principles of Animal Ecology' by Alee, *et al.* (1949), deals with all the major aspects of ecological work.²⁵ 'Natural Communities' by Dice (1952), properly deals with the community in terms of physical factors territoriality, food, succession and evaluation.²⁶ A most scholarly work by Andrewartha and Birch, 'The Distribution and Abundance of Animals' (1954), covers a number of phases of ecological thought never before presented in a single volume.²⁷ C.B. Knight (1965), in his book "Basic Concept of Ecology" designed introductory ecology also useful for the person who belongs to other disciplines like wildlife management, forestry and agriculture. He explained the very basic concepts of ecology and defined various ecological terms which should be known to every young ecologist.²⁸ Peter Farb in 1968, gave an ecological account for the distribution of plants and animals on the globe in these words "all animals and plants live where they do for a very good reason. If they are absent from an area that support similar organisms, there are good reasons for that too. They may be prevented from getting there by such visible but equally insurmountable barriers of insufficient water, or the wrong kind of food, or subtle conditions of climate or soil. Sometimes, they are inhibited by the presence of man, more often by the presence of another competing type. Sometimes, an animal or plant appears entirely suited to an environment and is still absent from it. This may be because of the absence of another on which it depends. The distribution of the econite plant is a good example, it is wholly depended on the bumble-bee for cross-pollination, and as a result is never found beyond the range of the bumble-bee itself."²⁹ Cox, C.B. *etal.* (1973), deal very well the organism's ecological relationships with soil, temperature etc. and causes of their distribution why these different species found in different areas of the globe.³⁰ Colinvaux³¹ in the same year tried to solve the problems like "why did the vegetation of

different parts of the world look different." In 1974, Robert W. Poole gave a brief account of quantitative methods to determine the causes of some ecological phenomena.³² Mann (1982)³³ and Seed (1986)³⁴ gave a detailed account of coastal ecology in their books 'Ecology of Coastal Waters' and 'The Ecology of Rocky Coasts' respectively and covered almost all the issues of problems and prospects of coastal biomass and ways for their conservation to maintain ecological balance. Sir Edmond Hillary in 1984, covered various issues of changing face of the earth like expanding deserts, extinction of flora and fauna, water and atmospheric pollution, climatic change, politics of ecology and their consequences in future.³⁵ The Great U-Turn by Goldsmith (1992), compiled a series of essays written during the last sixteen years with radical approach, and published in 'The Ecologist'. The general themes of the essays are ecology of unemployment, ecology of health, ecology of wars and social and ecological interpretation to the fall of Roman Empire.³⁶ Hayward (1994), offers a new and accessible introduction to the implications of ecology for social and political thought. A range of debates about values in nature, the meaning of sustainable development and such questions as whether human rights are compatible with ecological responsibilities are discussed in a very judicious manner.³⁷

A Brief Account of the Work done in the Region

Agro-ecological studies in Indian context and of Himalayan region in particular are done by non-Indian up to the independence specially in the writings of great hunters and forest officers which was later on took over by the Indians. A brief compilation of such studies is as follows:

Semple (1911)³⁸, while describing the stock grazings on the slopes of Kashmir valley pointed out towards an ecologically beneficial change in the landuse pattern. In the same year Semple, in a paper "Influences of Mountainous Environment" had tried to stress the need of integrated

approach of mountain slope and valley agriculture planning.

Mason (1929)³⁹, while describing the routes of western Himalaya had pointed out that the deterioration of living environment in the caravan nodal centres would become a stressing problem if allowed to sprawl on the fringes of virgin forests. This shows that in the early decades of this century, geographers and environmentalists have been consciously aware of the after-effects of reckless handling of ecological issues.

The study of Agricultural landuse of Kashmir valley with ecological methods was carried out by Hoon (1955)⁴⁰, when he described the agricultural landuse on the basis of soil characteristics. But he limited the study to hilly areas only where slope, as seemed to him was the main restricting factor of soil formation. Later, Koul (1956)⁴¹, presented altitude based soil zones for agricultural landuse. Datta and others (1957)⁴², studied the agro-ecological conditions of the valley for agricultural landuse when they analyzed the Karewa soils and rainfall characteristics for saffron cultivation. Singh (1958)⁴³, while referring towards the depletion of forests in the valley made an ecological analysis of agricultural landuse and soil erosion. Stamp (1960)⁴⁴, described the importance of Kashmir valley ecology in the whole region of western Himalaya and possibilities of crop diversification in the Kashmir valley. Raina (1962)⁴⁵, while discussing the scope for rural landscape in the Kashmir valley has analysed the role of rainfall and temperature in shaping the cropping pattern in different relief divisions of the Kashmir valley. Jalal (1977)⁴⁶, has taken into account productivity per unit (PPU) for land capability classification in Pithoragarh district of U.P. Hudson (1979), classified the land of U.P. hills into six capability classes based on soil depth and slope. Singh (1980), Singh and Kaur (1983) and Chadha (1989) gave accounts to conserve the Himalayan ecology in more or less similar ways. The poor environmental management in

creating shortage of food, fuel and fodder, out migration and poverty seems to conspired with nature catastrophe, influencing the worst injuries to the highlands. The rapid deforestation is causing soil erosion and ubranization along with unplanned tourism development in ecologically fragile Himalayan region. The solutions of the said problems are suggested in eco-development i.e., development without destruction, the environmental consciousness and to know how much exploitation of natural resource and any economic activity is too much? Shah (1982a, 1982b, 1983, 1991), emphasizing the need of a pragmatic approach based on environmental and economic considerations has made remarkable contribution towards land capability classification in Himalaya. Sen (1986)⁴⁷, indicates that the existing landuse pattern in the hill is deteriorating the ecosystem and suggested that, the land unsuitable for cultivation of foodgrains should not be used for regular cultivation but to be put under permanent vegetation like Orchards and other perennial crops in the hills. Raza (1987), made an attempt to develop an understanding between diversities and disparities of the nature.⁴⁸

Mukherjee (1987)⁴⁹, identifies the major causes of imbalances in the ecosystem and suggests remedial measure for its conservation and restoration. It is pointed out that the human intervention into the natural realm for the exploitation of resource base in terms of mining, deforestation and agricultural landuse has resulted in serious ecological disorders. The work of Dhaliwal and Kler (1995)⁵⁰, "Principle of Agricultural Ecology" is really a masterpiece for the researchers not only in agro-ecology but also in other disciplines i.e., life sciences and environmental sciences. It deals the very basic concepts of ecology, agro-ecosystem, current status of various natural resources and their management to feed the growing population of the world. Misra (1998), said about the three dimensions of environmental sustainability in biodiversity which has to be seen

from three perspectives i.e., genetic diversity, species diversity and ecosystem diversity.⁵¹ Singh (1999)⁵², compiled the work of Canadian International Development Agency (CIDA) and Shastri Indo-Canadian Institute (SICI) on Sustainable Development of Mountain Environment in India and Canada. The focussed regions for this study are Himachal Pradesh in India while Arrow Lake region of British Columbia in Canada. It covers various issues of natural resource mismanagement and their judicious conservation. Rawat, Kumar and Singh (1999)⁵³, edited a book on the theme "Environmental Management and Regional Development in the Himalaya" with special reference to U.P. Himalaya, in which they discussed a large number of burning issues related to the sustainable development of the region and their cure with the application of most advanced techniques of Remote Sensing and GIS at micro-level. Mohan (2000)⁵⁴, highlights the multidimensional nature of ecological issues that have been emerged as a consequence of rapid economic growth with special reference to Indo-Gangetic Divide and adjoining region.

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