



An Instructional Material On LAND USE PLANNING AND WATERSHED MANAGEMENT

Ajeet Kumar, Dr. A.K. Singh, Dr. C.K. Jha

► To cite this version:

Ajeet Kumar, Dr. A.K. Singh, Dr. C.K. Jha. An Instructional Material On LAND USE PLANNING AND WATERSHED MANAGEMENT. Doctoral. LAND USE PLANNING AND WATERSHED MANAGEMENT, India. 2021, pp.1-82. {hal-05202051}

HAL Id: hal-05202051

<https://hal.science/hal-05202051v1>

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Dr. Rajendra Prasad Central Agricultural University

Pusa (Samastipur)-Bihar- 848125

An Instructional Material

On

LAND USE PLANNING AND WATERSHED MANAGEMENT

COURSE NO.: SOILS-606

CREDIT HOUR: 2 (2+0)



Dr. Ajeet Kumar

**Assistant Professor-cum-Scientist, Department of Soil Science
Sugarcane Research Institute, RPCAU, Pusa**

Dr. A.K. Singh

Assistant Professor, Department of Soil Science, PGCA, RPCAU, Pusa

Dr. C.K. Jha

**Assistant Professor-cum-Scientist, Department of Soil Science
Sugarcane Research Institute, RPCAU, Pusa**

July-2021

Objective of the course: To teach the better utilization of land for agricultural purposes, and better management of run-off or surplus/excessive rain-water in the catchment area for agricultural purposes in a watershed.

Lecture outlines

Sl. No.	Topic	Page No.
1.	Concept and techniques of land use planning, Characteristics of land, Importance of land, Different land types, Land Use Planning:-Definitions, Objectives, Importance and Principle of land use planning.	4-7
2.	Concepts related to land use:-Reversible Uses, Irreversible Uses, Multiple Land Uses, Compatible and Incompatible land uses, Highest and Best Use of the Land, Comprehensive Land Use Planning.	8-9
3.	Factors governing present land use planning, Physical - economic - social factors - residential growth - housing density - government proposals - multiplier effect - road policies (Private Finance Initiative)	10-11
4.	Land evaluation methods and soil-site suitability evaluation for different crops	12-14
5.	Land capability classification and constraints in application	15-21
6.	Agro-ecological regions/sub-regions of India and their characteristics in relation to crop production.	22-51
7.	Water harvesting - concept, significance, types, methodology; Use of harvested water in agriculture to increase water productivity.	52-60
8.	Watershed development / management - Introduction concept, objectives, characterization, planning, execution, community participation and evaluation	61-68
9.	Rehabilitation of watershed; Participatory Rural Appraisal (PRA) Approach for Watershed Management	69-80
10.	Developing economically and ecologically sustainable agro-forestry systems for watershed, Case studies	81-82



Suggested Readings

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Concept and techniques of land use planning

Land: The definition of land is the part of the surface of the Earth that is solid ground and not water. Land is an area of ground, especially one that is used for a particular purpose.

Characteristics of land

Land possesses the following characteristics:

- ❖ Free Gift of Nature
- ❖ Fixed Quantity
- ❖ Land is Permanent
- ❖ Land is a Primary Factor of Production
- ❖ Land is a Passive Factor of Production
- ❖ Land is Immovable
- ❖ Land has some Original Indestructible Powers
- ❖ Land Differs in Fertility

Importance of land

Land is a natural resource of utmost importance. It supports natural vegetation, wild life, human life, economic activities, transport and communication systems. Land resource is important because humans not only live but also perform all economic activities on land. Besides, land also supports wild life, natural vegetation, and transport and communication activities. Ninety five percent of our basic needs and requirements like food, clothing and shelter are obtained from land. Land as a factor of production is of immense importance. The economic prosperity of a country is closely linked with the richness of her natural resources. Land is considered as an important resource as it provides habitation to a wide variety of flora and fauna. It is used by human beings for various purposes such as agriculture, forestry, and mining, building houses and roads, and setting up industries. The use of land is determined by physical factors such as topography, soil, climate, minerals and availability of water. Human factors such as population and technology are also important determinants of land use pattern.

Types of land

These can include residential, institutional, business, industrial, agricultural, forestry, park, and other relatively natural land uses. Each of these broader categories can be further subdivided, based on the nature and intensity of the activities that are undertaken.

Different land types

The different types of land are known as **biomes**. These are divided into four classifications: **desert, forest, grassland and tundra**. Land biomes are typically defined by the type of vegetation they possess, the types of animals that inhabit them and their climate, such as rainfall and temperature.



Land use:

Land Use refers to the manner of utilization of land, including its allocation, development and management. Land use is the term used to describe the human use of land. It represents the economic and cultural activities (e.g., agricultural, residential, industrial, mining, and recreational uses) that are practiced at a given place. Public and private lands frequently represent very different uses.

Types of land uses

There are different categories when it comes to land use. The five most common uses are recreational, transport, agricultural, residential and commercial. Understanding the specifics of each one can help when planning on investing in property.

Land Use Planning:

Definitions

Refers to the rational and judicious approach of allocating available land resources to different land using activities and for different functions consistent with the overall development vision/goal of a particular city. It also refers to a document embodying a set of policies accompanied by maps and similar illustrations which represent the community desired pattern of population distribution and a proposal for the future allocation of land to the various land-using activities.

OBJECTIVES

1. To promote efficient utilization, acquisition and disposition of land ensure the highest and best use of land
2. To direct, harmonize and influence discussions and activities of the private and public sectors relative to the use and management of lands
3. To reconcile land use conflicts and proposals between and among individuals, private and government entities relative to the present and future need for the land

4. To promote desirable patterns of land uses to prevent wasteful development and minimize the cost of public infrastructure and utilities and other social services
5. To preserve areas of ecological, aesthetic, historical and cultural significance.

Importance of land use planning

Land-use planning can **help coordinate various land uses in a watershed, thereby minimizing conflicts and sustaining water quantity and quality for future generations**. This schematic represents typical land uses and conservation strategies that might be found in a coastal mountain watershed.



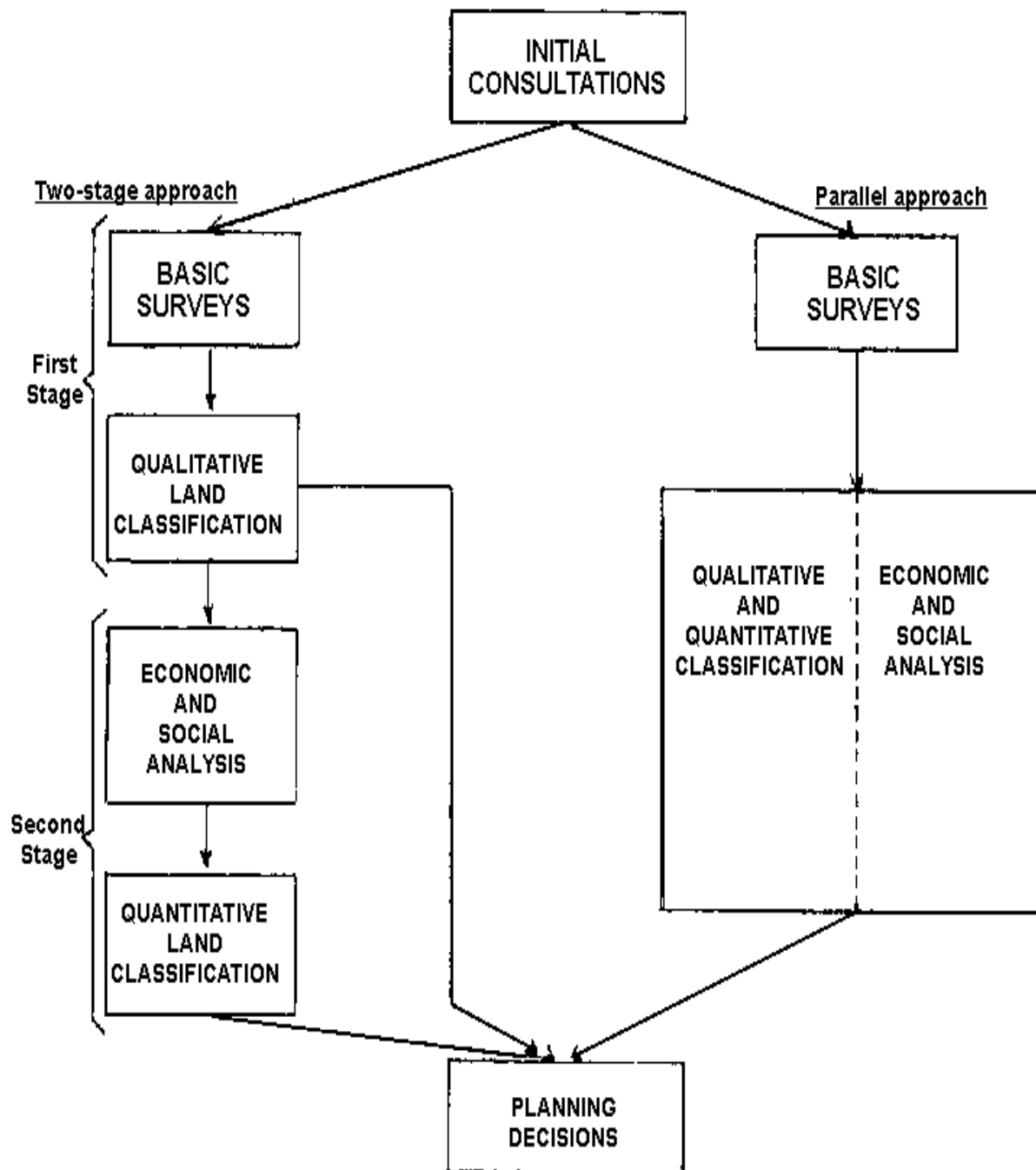
Function of land use planning

The function of land use planning is to guide **decisions on land use** in such a way that the **resources of the environment** are put to the most **beneficial use for man**, while at the same time **conserving** those **resources** for the future.

Principle of land use planning

Land evaluation is only part of the process of land use planning. Its precise role varies in different circumstances. In the present context it is sufficient to represent the land use planning process by the following generalized sequence of activities and decisions.

1. Recognition of a need for change;
2. Identification of aims;
3. Formulation of proposals, involving alternative forms of land use, and recognition of their main requirements
4. Recognition and delineation of the different types of land present in the area;
5. Comparison and evaluation of each type of land for the different uses;
6. Selection of a preferred use for each type of land;
7. Project design, or other detailed analysis of a selected set of alternatives for distinct parts of the area; this, in certain cases, may take the form of a feasibility study.
8. Decision to implement;
9. Implementation;
10. Monitoring of the operation.



Types of land use planning

There are five main different types of land use: **residential, agricultural, recreation, transportation, and commercial**. Managing the various uses of land occurs through partnerships between state, federal, and municipal entities, but many decisions affecting local projects occur at the municipal level

CONCEPTS RELATED TO LAND USE



CONCEPTS RELATED TO LAND USE

1. **REVERSIBLE USES:** cases when the inherent features and characteristics of the land have not been considerably altered or modified such that the soil horizon, landform, and structure remain intact so that the land can be reverted to its former use or original condition
2. **IRREVERSIBLE USES:** when land is subject to applications which brought about changes, alteration or modifications so much so that it is physically impossible to restore the land to its previous state or condition
3. **MULTIPLE LAND USES:** combining different land uses, whether reversible or irreversible, in an orderly and desirable pattern because:
 - a. Land is finite and supply is finite
 - b. Demand is ever increasing
 - c. Competition is there

Land can indeed have more than one use and uses can be combined in different ways.

4. **COMPATIBLE AND INCOMPATIBLE LAND USES:**– a related concept of multiple uses of land is the compatibility of uses. Some land uses are innately

incompatible while others are completely compatible. Compatible uses can coexist harmoniously and effectively in an orderly management.

5. HIGHEST AND BEST USE OF THE LAND:

- a. The use of land which generates the maximum profit without negative consequences especially on the environment
- b. Land should be used in such a manner consistent with its natural qualities to maximize its productivity and also adhere to the principles of sustainable development.
- c. It is utilizing land in a manner that is beneficial to both man and environment

6. COMPREHENSIVE LAND USE PLANNING: A document embodying specific proposals for guiding, regulating growth and development of a city or municipality.

Factors governing present land use

Factors influencing land use: Physical - economic - social factors - residential growth - housing density - government proposals - multiplier effect - road policies (Private Finance Initiative)

Main points

- The amounts of land used for each purpose are constantly changing
- Land use can be influenced by many factors -
 - **Physical** - soil fertility, soil drainage, slope angle, aspect, scenery, mineral potential etc.
 - **Economic** - distance from markets, demand for different uses.
 - **Social** - population size, legislation, government policies
- The biggest single land use change in the UK is the growth of residential areas.
- Housing density (number of dwellings/hectare) has a huge impact on the land use pressure. A bigger housing density means less land is used.
- Low density development (less than 20-25 dwellings per hectare) is unlikely to sustain local services or public transport, creating increased dependence on car use. The government proposes to set minimum densities for new development and to oppose low density developments.
- During the period 1989 to 1997 housing was built at an average density of
 - 28 dwellings per hectare on previously developed land-eg. urban redevelopments
 - 21 dwellings per hectare on land not previously developed (eg green field sites. Ironically, these low densities meant a large area of green field land was used to create a small amount of housing!
 - The average density ranged from 22 dwellings per hectare in the South East and East Midlands, to 47 dwellings per hectare in London where higher land prices forced more efficient use of the space
- There are knock on ("multiplier") effects with residential developments. More houses need more roads to service them.
- Increases in the road system increase the demand for land both directly (by pass routes etc) and indirectly (250,000 tonnes of sand and gravel are required for each mile of motorway).

- Government road policies can **increase** the pressure to build new roads. For example, recent roads such as the A30 Exeter - Honiton expansion are part of the Government's Private Finance Initiative. They are privately designed, built, financed and operated. The international consortium *Connect* will foot the bill for the A30's design, construction and maintenance (initial outlay estimated at £75m). They will be paid back by the Government over 30 years through a system based on the amount of traffic. It is therefore in *Connect's* interest to encourage traffic growth by stimulating residential development along the road, commercial developments such as an extension to Exeter airport / shops etc and a woodland leisure complex.

Land evaluation methods and soil-site suitability evaluation for different crops

Land Use Planning Definitions:

- Refers to the rational and judicious approach of allocating available land resources to different land using activities and for different functions consistent with the overall development vision/goal of a particular city
- refers to a document embodying a set of policies accompanied by maps and similar illustrations which represent the community desired pattern of population distribution and a proposal for the future allocation of land to the various land-using activities.

METHODS OF LAND EVALUATION AND LAND USE PLANNING

The demands for natural resources information have widened - from emphasis on specialist data; to land evaluation, predicting the potential of land for one or more uses; to land use planning involving consideration of land use problems and opportunities, generation of a range of land use options, and making choices between these options (Dent 1991, FAO 1993 in press).

Early impetus for this direction came from soil conservation issues and from land settlement and irrigation schemes. Most interpretations of natural resources data have been physical ones - either predicted physical response to various land uses or in terms of constraints on such uses. Where financial appraisal has been demanded, this has been tacked on without much change in procedure, either from natural resources specialists or economists.

The step from land evaluation to land use planning is a big one and goes beyond the physical and financial assessment of natural resources. Where conflicts of interest arise, conventional methods have been found wanting, and possible future directions are largely untried. In this chapter, the logic and assumptions of conventional methods of land evaluation and land use planning are reviewed according to their principles - from trial-and-error, to the transfer of experience by analogy, to simulation models (McKenzie 1991, Dreissen and Konijn 1991).

Chapter deals with what now seems to be the stumbling block to more effective use of natural resources information and rational land use planning - the need for participation in the process by all the stakeholders.

Trial and Error

This is the oldest way of adapting land use to changing circumstances; the only way in the absence of a scientifically-based program of resource survey and evaluation; and still the usual way. However, the economic, social and environmental costs can be very high and it is difficult to develop a rational strategy for new areas, new problems and new opportunities. Usually, the experience gained is not recorded and most is lost when managers change.

Transfer of Experience by Analogy

The results of a land use trial, be it a farmer's experience, a field experiment or a catchment study, are strictly applicable only to that site and, may be, only to that time. The assumption that underlies soil survey, land systems survey, and most methods of land evaluation is that this experience can be transferred to other sites by analogy - by assuming that all occurrences of a particular class of land (the land analogue) will respond in the same way to the same treatments. Transfer by analogy needs a classification of land that permits the prediction of performance or behaviour over a wide range of land uses. The analogues have to be identified in the field even though the attributes of the land that determine performance may not be known or not visible in the field. Analogues may be defined by classifications of soil, e.g. Soil Series, or land, e.g. Land Systems. For example, if trials are carried out on Mondha Series, a Typic Chromustert (NBSS & LUP 1987), we assume that these results apply to all soils of Mondha Series and, to some extent, all Usterts. The method relies on detailed characterisation of the trial sites and tightly-defined analogues that are rigorously correlated in the field, across the country and within the higher levels of the taxonomy. This is a substantial and demanding task that has been achieved by only a few survey organisations. It is possible to improve a system of classification in the light of experience. The present amendments to Soil Taxonomy (Soil Survey Staff 1990) are the fifth published amendments since the definitive version of 1975. However, the combinations and values of land characteristics that determine the performance of one crop (or system of management) in one environment are not the same for other crops and/or other environments (Gibbons 1961), so it becomes difficult to define a manageable number of land analogues (about 10 000 Soil Series are established in the USA). For precision in the transfer of experience, we are forced to adopt narrowly-defined mapping units (e.g. phases of Soil Series) that can only be mapped at large scales. National soil survey coverage at this level has proved not to be a practicable proposition for poor countries, and for most rich ones too.

Empirical Land Evaluation Using Expert Knowledge

Expert knowledge of land response to management can be used to interpret natural resources data to provide information that is, at once, more accessible and more focussed on land management than the basic data. Four approaches have been widely adopted: Land Capability Classification, FAO Framework for Land Evaluation, USBR (United States Bureau of Reclamation) land classification system for irrigation schemes, and Parametric Indices. More recently, decision trees have been advocated as a more transparent way of using expert knowledge so that it can be built upon by the manager or decision maker in the field.

Land capability classification and constraints in application

Land capability classification (LCC) may be defined as a system of grouping land in to various classes based on inherent limitations imposed on sustained use by soil attributes, topography, drainage and climate. The guiding principle underlying LCC is “use land according to its capability and treat it as per its need.

Land Capability Classification

The best known and most widely used method is Land Capability Classification, originally developed by the United States Soil Conservation Service in the 1930s to interpret conventional 1:20 000 soil maps for farm planning (Hockensmith and Steele 1949). The definitive account of the system is given by Klingebiel and Montgomery (1961). It has been adopted and, sometimes, modified by survey organisations in many developing countries. Land is classified according to the degree of its limitations for sustained use and the soil conservation measures necessary to maintain it in productive use (Table 7). The limitations to use that are considered are those not feasible for the farmer to correct (e.g. climate, slope, soil depth, liability to flooding) and these are recognized at subclass level. A third level of classification, within the subclass, is the capability unit which groups soils that require similar management and are suitable for similar crops. Land allocated to a particular class has capability for the defined land use (e.g. Class I: arable, no restrictions) and all uses allowed for lower classes (so Class I is also suitable for grazing, forestry and wildlife). This does not necessarily indicate which use is most productive or profitable. The classification assumes the technical means, capital resources and skills of the better farmers under local conditions and a favourable ratio of outputs to inputs. Access to markets, shape and size of land parcels and land ownership are not considered.

Limitations of land capability

These are subdivisions of capability classes, made on the basis of four dominating limitations, namely, (i) risk of erosion (e), (ii) wetness, drainage or overflow (w), (iii) rooting zone limitations (s), and (iv) climatic limitations (c).

Table 1: Land Capability Classes of the USDA Soil Conservation Service

CLASS	DESCRIPTION
I	Soils with few limitations
II	Soils with limitations that reduce the choice of crops or require simple soil conservation practices
III	Soils with severe limitations that reduce the choice of crops and/or require special conservation practices
IV	Soils with very severe limitations that restrict the choice of crops and/or require very careful management
V	Soils with little or no erosion hazard but with other limitations that limit their use largely to pasture, range, woodland or wildlife
VI	Soils with very severe limitations that restrict their use to pasture, range, woodland or wildlife
VII	Soils with very severe limitations that restrict their use to range, woodland or wildlife
VIII	Soils and landforms with limitations that preclude commercial crops and restrict their use to recreation, wildlife and water supply

There is an in-built assumption that the most desirable land use is arable cropping requiring no special conservation practices. This determines the choice of limiting factors and the values of limiting land characteristics assigned as class boundaries:

Class		
I	Arable (all crops, no conservation practices)	Most desirable
II, III, IV	Arable (increasingly costly conservation practices and or restricted choice of crops)	
VI	Improved pastures	
VII	Grazing of natural range, or forestry	 ▼
VIII	Recreation, wildlife, water catchment	Least desirable

Class V is an oddball for limitations other than erosion; in practice it is used for wetland

Expert judgement and field testing are needed to specify the criteria for classes and subclasses, and the strength and wide application of the system lies in this flexibility - criteria appropriate to local conditions should be specified. Table 8 shows the conversion table drawn up for Malawi by Shaxson et al. (1977), who also prescribe the soil conservation practices to be followed in each subclass. Astonishingly, the original USDA criteria have sometimes been adopted without change in quite different technological and physical environments. Land capability classification is relatively easy to do and easy to use. Shaxson (1981) shows how class and subclass can be mapped quickly and directly, without bothering with time-consuming soil survey. Users are much more comfortable with land capability maps than soil maps or other complex land resource surveys (e.g. Woode 1981). After all, class I is obviously the best, class III is less good and class VI is rubbish, isn't it ? Well, no, but the assumptions and shortcomings of the system are not immediately obvious. The most obvious shortcoming is that land cannot be graded from best to worst irrespective of the kind of management. Some kinds of use have special requirements and tolerances that others do not have, for example: - Rice requires a soil with a high available water content and tolerates prolonged flooding; other cereals will not tolerate waterlogging during their period of active growth; - Tea, sugar cane and oil palm need efficient transport to processing plants and so have a minimum area requirement; grain grown for subsistence does not; - For mechanised operations, stones and rock outcrops are limiting, but with oxen or hand hoeing you can work round them. The arable bias of Land Capability Classification and the very generalised nature of the information does not help choice between alternative uses, except to eliminate the grossly unsuitable. Land use, productivity and profitability are often poorly correlated with land capability class (Smit et al. 1984, Burnham et al. 1987). No one-shot land evaluation can provide the information needed to choose between two or several land use options and, thus, match land use closely with land suitability. These objections were addressed in the FAO Framework for Land Evaluation (1976).

Structure of the FAO Framework for Land Evaluation

The target set by the FAO Framework is a four category evaluation:

1. Land suitability orders.

The first categorization is into SUITABLE/NOT SUITABLE for a specified land use type - dubbed land suitability orders.

- a. Suitable means that sustained use of the kind under consideration will yield benefits which justify the inputs without unacceptable risk of damage to land resources.
- b. Not suitable means that the kind of land use is technically impracticable, or would cause unacceptable degradation of land resources, or that the value of expected benefits does not justify the expected costs of needed inputs.

2. Land suitability classes.

These reflect degrees of suitability. Experience of testing land suitability evaluations against crop performance is very limited. Such experience as there is does not support a detailed sub-division. Two classes may be enough; FAO recommends not more than three, as follow:

- a. **Class S1** land having no significant limitations to sustained use, or with only minor limitations that will not significantly reduce productivity or benefits and will not raise inputs above an acceptable level;
- b. **Class S2** land having limitations that, in aggregate, will reduce productivity or benefits and will increase required inputs so that the advantage to be gained from the land use - though still attractive - will be less than that expected on Class S1 land;
- c. **Class S3** land having limitations that, in aggregate, are so severe that expenditure on the land use will be only marginally justified.

Within the order Not Suitable, there are two classes:

Class N1: Currently not suitable. This land could be used for the purpose under consideration but the social or economic cost is, at present, unjustified;

Class N2: Permanently not suitable. Land having limitations that appear so severe that sustained use is not possible.

3. **Land suitability subclasses.** These reflect the kinds of limitations, e.g. water deficiency, erosion hazard - S2w, S3e. There are no subclasses within S1.
4. **Land suitability units.** These are subdivisions of a subclass which differ in their response to management. Units are significant at the farm level. They are distinguished by arabic numbers, e.g. S2e - 1, S2e - 2.

From Land Evaluation to Land Use Planning

Land users have always made land use plans, whether formally or informally. There is also a long history of sectoral planning. All this has been ad hoc, for individual farms, plantations, forests or parks, or narrow sectoral purposes - water resources development,

roads, etc. While no clearly-defined planning methodology is discernable, conventional approaches have developed within individual sectors. For instance, meeting objectives for both wildlife conservation and development has been greatly assisted through designating particular management categories. Most countries follow the categories defined by IUCN (1982):

- i. Scientific reserve/strict nature reserve
- ii. National park
- iii. Natural monument/natural landmark
- iv. Managed nature reserve/wildlife sanctuary
- v. Protected landscape or seascape
- vi. Resource reserve
- vii. Natural biotic area/anthropological reserve
- viii. Multiple use management area/managed resource area
- ix. Biosphere reserve
- x. Natural world heritage site

It is usual to prepare management plans for protected areas designated within these categories. These tend to adopt a standard approach providing baseline information (e.g. on landscapes, fauna, flora) and including prescriptions for use and development covering, for example, zoning, visitor management, resource management (e.g. fire control, game cropping, hunting quotas), research, infrastructure, education, etc. The master plans for national parks and wildlife management in Malawi are an excellent example (Clarke 1983). In the forestry sector, many countries have designated areas in various categories (e.g. protected forest areas, forest reserves, plantations) and have prepared management plans for such areas. Recently, legal categories have been defined for forests and forest lands by functions and by conditions (ITTO 1993):

1. Protection forests
 - 1.1 Protection forests on fragile land
 - 1.2 Forests set aside for plant and animal species and ecosystem preservation
 - 1.3 Totally protected areas
2. Production forests
3. Conversion forests

Frequently, protected forests are also designated as protected areas under the IUCN protected area categories. There are no universally agreed criteria for preparing management plans for these and other forest categories. Usually, plans describe the forest types and

percentage cover, the standing stock, management objectives, logging quotas, controls and plans for regeneration/replanting. Such planning is often effective within its own narrow terms of reference, so long as the planning agency is also the executive agency and has some freedom of action; and so long as there are few conflicts of interest. Land use planning has been most effective and, sometimes, successful in settlement of empty land and in new plantation and irrigation developments. In these cases, administrative or engineering concerns have been paramount. Limited natural resources information has been used to guide the physical layout of farms, roads and the water distribution system and in the choice of crops. A good example is the work by Hunting Technical Services (1980/81) for the Mahaweli irrigation development in Sri Lanka (Dent and Goonewardene 1993). Social aspects have received generally less attention, in some cases leading to conflict, e.g. the case of Barabaig pastoralists affected by the Tanzania-Canada wheat production scheme in Hanang District, Tanzania.

Management of natural resources is much more difficult when there are many independent decisionmakers and management units, several sectoral and administrative authorities, and conflicts of interest between the various stakeholders. This situation is typical of local-level land use plans undertaken by district or provincial teams within the Department of Agriculture or an Integrated Rural Development Plan. The techniques have been adapted from farm planning and small-scale engineering development for settler farms, often based on a soil or land capability survey. Several national or departmental manuals have been drawn up and these show strong family relationships. For example, the manuals of the Land Use Services Division (1970) - later the Land Use Branch (Zambia Dept.Agric. 1977) in Zambia, and by Shaxon et.al. (1977) in Malawi, evolved out of earlier manuals prepared by the Department of Conservation and Extension (CONEX) of the Federation of Rhodesia and Nyasaland. In Zambia, for example, land use plans follow a conventional format covering description of area, history, physical conditions, resources, population, communications, present land use, assessment of agricultural potential, proposals for land use, plot demarcation, bush clearing, extension program, roads, water supplies, soil conservation, staff and housing, economic appraisal, etc. Good examples are the North Nyamphande Settlement Scheme (Wilson and Bourne 1971) and the Msandile Catchment Plan (Wilson and Priestley, 1974). The difficulties of implementing land use plans in settled areas that have inherited many and complex problems of land use have already been mentioned in Chapter Three. These difficulties stem from conflicts of interest within local communities, between government and local people and, not least, the failure of professional planners and

administrators to comprehend and respect these different goals. These various problems are exemplified by the case of the Barabaig in Tanzania (Box 20). There have also been difficulties in getting several agencies to work together and, often, a lack of technical solutions to land use problems that are practicable, profitable and easily-incorporated into existing farming systems

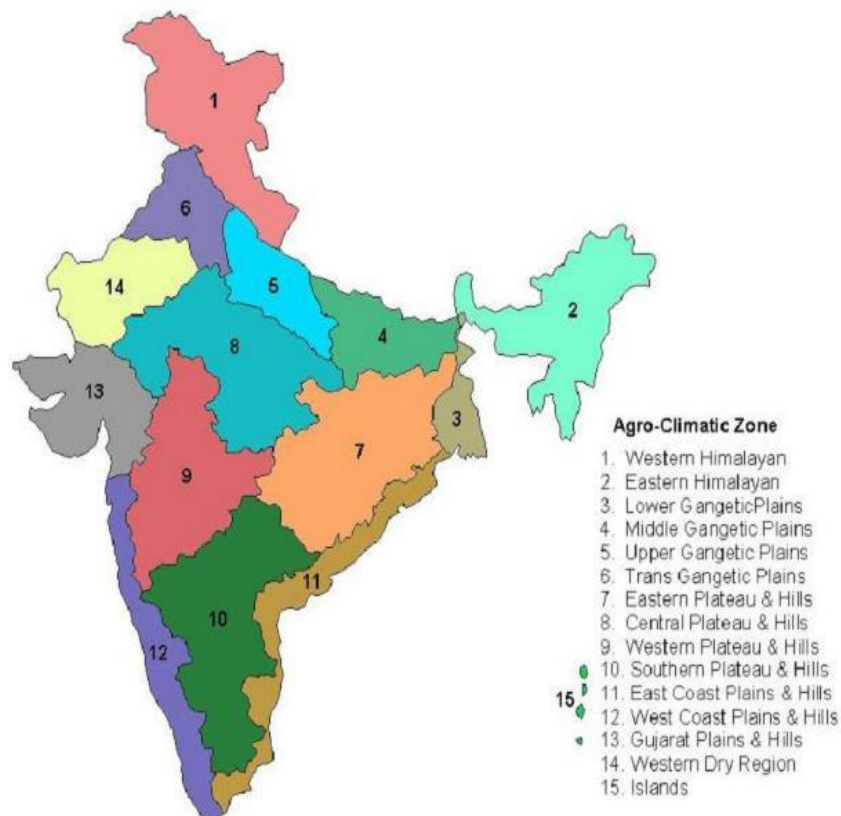
Agro-ecological regions/sub-regions of India and their characteristics in relation to crop production

Agriculture is highly dependent on soils and climate. The ever-increasing need for food to support the growing population in the country demands a systematic appraisal of its soil and climate resources in order to prepare effective land-use plans. India has a variety of landscapes and climate conditions and this is reflected in the development of different soils and types of vegetation. Based on 50 years of climate data and an up-to-date soil database, the country has been divided into 20 agro-ecological zones (AEZs). Each AEZ is as uniform as possible in terms of physiography, climate, and length of growing period and soil type for macro-level land-use planning and effective transfer of technology.

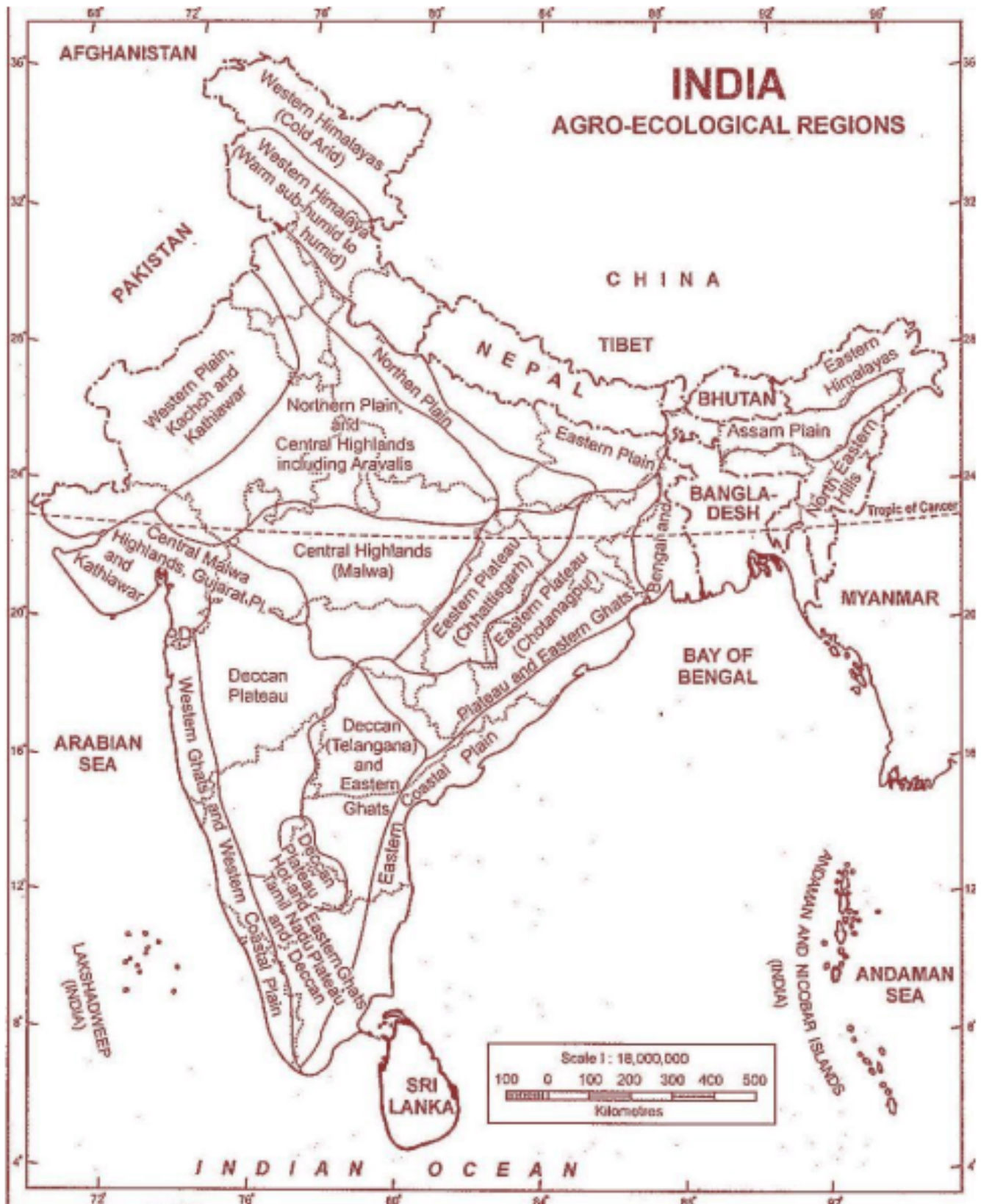
Classification:

Planning commission of India (1989) made an attempt to delineate the country into different agro climatic region based on homogeneity in rainfall, temperature, topography, cropping and farming system and water resource. India is divided into 15 agro-climatic regions.

Agro-climatic zones of India



Agro-Ecological Regions of India



Terminology

- ✚ An “**Agro-climatic zone**” is a land unit in terms of major climates, suitable for a certain range of crops and cultivars.
- ✚ An “**Agro-ecological zone**” is the land unit carved out of agro-climatic zone superimposed on different landforms and soil conditions which acts as modifier of climate and length of growing period.
- ✚ **Length of Growing Period (LGP):** The length of growing period refers to number of days in a year during which rainfall and moisture stored in the soil exceeds half of potential evapotranspiration. The spatial distribution of crops and farming systems in any region is determined by the LGP.
- ✚ An ecological zone is a landscape unit that unites certain interrelated animal and plant communities (**biocenosis**) with a particular social formation and environmental conditions as part of an integrated system.
- ✚ **Climate** is the average weather in a given area over a longer period of time.
- ✚ **Ecology** is the study of the relationships between living organisms, including humans, and their physical environment.



Important Features of Agro-ecological Zones of India

AEZ No.	Agro-ecological region	Geographical area (million ha)	Gross cropped area (million ha)	Physiography	Precipitation (mm)	PET (mm)	Length of growing period (days)	Major crops
1.	Cold arid ecoregion with shallow skeletal soils	15.2 (4.7%)	0.07	Western Himalayas	< 150	<800	< 90	Vegetables, millets, wheat, fodder, barley, pulses
2.	Hot arid ecoregion with desert and saline soils	31.9 (9.7%)	20.85	Western Plain & Kachchha Peninsula	< 300	1500–2000	< 90	Millets, fodder, pulses
3.	Hot arid ecoregion with red and black soils	4.9 (1.9%)	4.18	Deccan Plateau	400–500	1800–1900	< 90	Sorghum, safflower, cotton, groundnut, sunflower, sugar cane
4.	Hot semi-arid ecoregion with alluvium-derived soils	32.2 (9.8%)	30.05	Northern Plain & Central Highlands including parts of Gujarat Plains	500–800	1400–1900	90–150	Millets, wheat, pulses, maize; irrigated cotton & sugar cane
5.	Hot semi-arid ecoregion with medium and deep black soils	17.6 (5.4%)	11.04	Central (Malwa) Highlands, Gujarat Plains & Kathiawar Peninsula	500–1000	1600–2000	90–150	Millets, wheat, pulses
6.	Hot semi-arid ecoregion with shallow and medium (dominant) black soils	31.0 (9.5%)	25.02	Deccan Plateau	600–1000	1600–1800	90–150	Millets, cotton, pulses, sugar cane under irrigation
7.	Hot semi-arid ecoregion with red and black soils	16.5 (5.2%)	6.19	Deccan (Telangana) Plateau & Eastern Ghats	600–1000	1600–1700	90–150	Millets, oilseeds, rice, cotton & sugar cane under irrigation
8.	Hot semi-arid	19.1	6.96	Eastern Ghats (Tamil	600–1000	1300–	90–150	Millets, pulses,

	ecoregion with red loamy soils	(5.8%)		Nadu uplands) & Deccan Plateau (Karnataka)		1600		oilseeds (groundnut), sugar cane & rice under irrigation
9.	Hot subhumid (dry) ecoregion with alluvium-derived soils	12.1 (3.7%)	11.62	Northern Plain	1000–1200	1400–1800	150–180	Rice, wheat, pigeon pea, sugar cane, mustard, maize
10.	Hot subhumid ecoregion with red and black soils	22.3 (5.8%)	14.55	Central Highlands (Malwa & Bundelkhand)	1000–1500	1300–1500	150–180	Rice, wheat, sorghum, soybean, gram, pigeon pea
11.	Hot subhumid ecoregion with red and yellow soils	11.1 (4.3%)	6.47	Eastern Plateau (Chhattisgarh Region)	1200–1600	1400–1500	150–180	Rice, millets, wheat, pigeon pea, green gram, black gram
12.	Hot subhumid ecoregion with red and lateritic soils	26.8 (8.2%)	12.09	Eastern (Chhota Nagpur) Plateau and Eastern Ghats	1000–1600	1400–1700	150–180	Rice, pulses, millets
13.	Hot subhumid (moist) ecoregion with alluvium-derived soils	11.1 (3.4%)	10.95	Eastern Plains	1400–1600	1300–1500	180–210	Rice, wheat, sugar cane
14.	Warm subhumid to humid with inclusion of perhumid ecoregion with brown forest and podzolic soils	18.2 (5.6%)	3.20	Western Himalayas	1600–2000	800–1300	180–210	Wheat, millets, maize, rice
15.	Hot subhumid (moist) to humid (inclusion of perhumid) ecoregions with alluvial-derived soils	12.1 (3.7%)	8.99	Bengal Basin and Assam Plain	1400–2000	1000–1400	> 210	Rice, jute, plantation crops
16.	Warm perhumid ecoregion with brown	9.6 (2.9%)	1.37	Eastern Himalayas	2000–4000	<1000	> 210	Rice, millets, potato, maize, sesame,

	and red hill soils							Jhum* cultivation is common
17.	Warm perhumid ecoregion with red and lateritic soils	10.6 (3.3%)	1.56	North-Eastern Hills	1600–2600	1000–1100	> 210	Rice, millets, potato, plantation crops, Jhum* cultivation is common
18.	Hot subhumid to semi-arid ecoregion with coastal alluvium-derived soils	8.5 (2.6%)	6.12	Eastern Coastal Plains	900–1600	1200–1900	90>210	Rice, coconut, black gram, lentil, sunflower, groundnut
19.	Hot humid perhumid ecoregion with red, lateritic and alluvium-derived soils	11.1 (3.6%)	5.70	Western Ghats and Coastal Plains	2000–3200	1400–1600	> 210	Rice, tapioca, coconut, spices
20.	Hot humid / perhumid island ecoregion with red loamy and sandy soils	0.8 (0.3%)	0.05	Islands of Andaman & Nicobar and Lakshadweep	1600–3000	1400–1600	> 210	Rice, coconut, areca nut, oil palm

Agro-Ecological Regions of India

A detailed discussion of each of the 20 AERs of India and the 60 AESRs with reference to this climate, soil and land use, and the distinguishing features of the AESRs are also mentioned below. The constraints and potentials with regard to each AER have been analysed for determining suitable cropping systems to reduce deterioration in quality of land.

1. Cold Arid Eco-region with Shallow Skeletal Soils:

This eco-region represents an area of 15.2 million hectares (mha) in the north-western Himalayas pertaining to Ladakh and Gilgit districts. It occupies 4.7 per cent (329 m ha) of the entire geographical area of India.

Agro-Climate:

The climate has mild summer and harsh winter. The mean annual temperature is less than 8°C. The mean annual rainfall is less than 150 mm. The precipitation covers less than 15 per cent of the mean annual Potential Evapotranspiration (PET). The area has aridic soil moisture and cryic soil temperature regime with Length of Growing Period (LGP) being not more than 90 days annually.

Soils:

While the very high northern parts of the plateau are permanently covered by snow, the gently sloping to level valleys has skeletal and calcareous soils. The soils are alkaline in reaction and low to medium in organic matter content. The region is represented largely by Ladakh series, which is classified as Typic Cryorthent.

Use of Land:

The eco-region has few forest trees. Some 11.2 per cent of the land is in non-agricultural use (inclusive of culturable fallows), current fallow is 1.2 per cent and the net sown area is 2.5 per cent. In the cultivated land, the production per unit area is low. Vegetables are the foremost crops to be grown, followed by millets, wheat, fodder, pulses and barley, these five crops giving yields of 400 to 700 kg/ha. Alfa-alfa is produced among the cultivated fodders. The major fruits grown are apple and apricot. Where the livestock is concerned, the mule is more common than the sheep, goat and yak which dominate in that order. Pashmina goats graze in the area.

Drawbacks:

The harsh climate is constraint, particularly the cryic temperature regime which behaves as a thermal pan for the growth of crops. The soil is shallow, sandy and bouldery and

their moderate-to-high calcareous nature, which results in nutrient imbalance for crops. Moreover, the normal period of cultivation of crops is very narrow. This means that agriculture is restricted to the valleys during thawing period which occurs at the same time as the scanty rains in the eco-region.

AESRs:

(a) Eastern aspect of the Ladakh plateau: cold hyper-arid eco sub-region (ESR) shallow skeletal soils; LGP is < 60 days.

(b) Western aspect of Ladakh Plateau and north Kashmir Himalayas: cold to cool typic-arid ESR; shallow, loamy skeletal soils; LGP is 60-90 days.

2. Hot Arid Eco-region with Desert and Saline Soils:

The hot and arid eco-region covers the western plain, that is south-western parts of Haryana and Punjab, western parts of Rajasthan, the Kachchh peninsula and northern parts of Kathiawar peninsula (Gujarat). The eco-region occupies 9.78 per cent of the entire geographical area (31.9 m ha) of India.

Agro-climate:

The region has hot summers and cool winters (arid), with the mean annual precipitation being less than 400 mm. This covers only 15-20 per cent of the annual PET demand which is 1500-2000 mm. The result is that there is a huge water deficit every year. The region has aridic soil moisture and hyperthermic soil temperature regimes. The annual LGP is not more than 90 days.

Soils:

The area has sandy soils represented by Thar series. They are moderately calcareous and alkaline in reaction. Pali, Lakhpur and Nihalkhera series occur.

Use of Land:

Rainfed mono-cropping is practised. Rainy season crops of short duration, pearl millet, chari (fodder) and pulses, are cultivated in non-saline areas. Where irrigation is available, cotton, sugarcane, mustard, wheat and gram are cultivated. There is sparse, sporadic tropical thorn forest. The forest cover in the region has reduced from 15 per cent to almost 1 per cent, a shocking fall in forest cover.

Criteria Used for Agro-Ecological Delineation (Mandal et al 1999):

Sr. No.	Level	Criteria Used	Soil Physiography	Bioclimate	LGP
1.	Agroecological Regions of India(AER) (20 AER) (For resource planning)	Great group association (1:7 m scale)	Broad 15 divisions	Arid, Semiarid, Subhumid, Humid, Pertiumid (After Thomthwaite and Mather, 1955 and Penman PE)	<90 days; 90-150; 150-210; >210
2.	Agro-ecological subregions of India (60 AESR) (for resource planning at regional level)	Sub group association (1:1 m scale)	Sub division	Arid/tynic arid/hyper arid semiarid/ semi arid dry/semi arid moist sub umid/dry/moist humid, pertiumid of major physiography	<60 (with 30 days interval (to >330 days
3.	Agro-ecological zones at state level (for resource planning at state level)	Soil family association (1:250,000 scale)	Landform	Bio-climate computation based on subdivision level rainfall data LGP isolines	LGP isolines with 15 days interval
4.	Agro-ecological unit at district level (for resource planning at district level)	Soil series association (1:50,000 scale)	Geomorphic Unit	Bioclimate computation based on rainfall at block level	LGP isolines with 7 days or 10 days interval
5.	Agro-ecological unit at watershed level	Soil phase 1:5,000 scale)	Details of geomorphic units	Effective rainfall at unit level	LGP based on AWC (soil unit)

Drawbacks:

The scanty rainfall in the region means heavy water deficit, with acute droughtiness at the time of grain formation. The salinity of the soil results in physiological droughts that occur frequently. There is nutrient imbalance of nitrogen, phosphorous, zinc and iron in particular.

ASERs:

- a. **Marusthali:** Shallow and deep sandy desert soils; LGP is less than 60 days.
- b. **Kachchh Peninsula:** A deep loamy saline and alkali soil, LGP is less than 60 days.
- c. **Rajasthan Bagar, North Gujarat Plain and south-western Punjab Plain:** Deep, loamy desert soils (inclusion of saline phase); LGP is 60-90 days.
- d. **South Kachchh and North Kathiawar Peninsula:** Deep loamy saline and alkali soils; LGP is 60 days.

3. Hot Arid Eco-region with Red and Black Soils:

Covering an area of 4.9 m ha (1.5 per cent of the India's total geographical area) the region covers a part of the Deccan plateau comprising Bellary district, south-western parts of Bijapur district and Raichur district of Karnataka and Anantapur district of nearby Andhra Pradesh.

Agro-climate:

The eco-region has hot and dry summers and mild winters. The erratic rains, about 400-500 mm, cater to 20-25 per cent of the annual PET demand of 1800-1900 mm. severe drought conditions persist throughout the year with a gross water debit of 1500-1600 mm every year. The LGP is less than 90 days. The eco-region has the aridicustic soil moisture and isohyperthermic

Soil temperature regimes

Soils Shallow and medium red soils are dominant and these are slightly acidic and non-calcareous. Deep, clayey black soils are slightly alkaline and calcareous.

Use of Land:

The area has tropical thorn forests. Traditionally, the land is fallowed in the rainy season and crops are cultivated in the postrainy months on residual soil moisture. Pearl millet is grown with some risk during the rainy season in some places. The farmers have low yields under traditional management practices. Irrigated crops intensively grown are groundnut, sugarcane, sunflower and cotton.

Drawbacks:

Workable soil moisture in the case of black soils is of a narrow range. Subsoil sodicity affects soil structure, drainage and availability of oxygen particularly in black soils. High subsoil density in red soils limits rooting depth. When there are stormy cloud bursts, there is high runoff and erosion hazard. Crop failure occurs occasionally due to prolonged dry spells of weather during crop growing period.

ASER:

(a) **Karnataka plateau** (Rayalseema as inclusion)

4. Hot semi-arid eco-region with alluvium derived soils:

Comprising parts of Gujarat, the northern plains and central highlands, this region has an area of 32.3 m ha (9.8 per cent of the geographical area of India).

Agro-climate:

The region has hot and dry summers and cool winters. Annual precipitation is 500-1000 mm, with an increasing trend from the west to the east direction. It meets 35-42 per cent of the mean annual PET demand of 1400- 1900 mm. Water deficit is around 700-1000 mm annually. The LGP is 90-150 days. The soil moisture regime is typicustic and soil temperature regime, hyperthermic. Droughtiness may affect parts of Bundelkhand region (Banda, Jhansi, Hamirpur, Datia and Jalaun districts).

Soils:

The soils are deep loamy alluvium-derived soils or deep loamy and clayey mixed red and black soils.

Use of Land:

The eco-region has tropical dry deciduous and thorn forests. Some 35 per cent of the area is traditionally rainfed while the remaining 65 per cent is under irrigated agriculture. In the northern plain, tube-well irrigation helps in overcoming droughty climate. The crops (kharif and rabi) grown are rice, millets, maize, pulses, berseem, wheat, mustard and sugarcane. In the central highlands (Bundelkhand), about 75 per cent of the net cropped area is subjected to rainfed agriculture and less than 25 per cent is irrigated. Kharif crops like jowar, pigeonpea and soybean and rabi crops of pulses, lentil and wheat are cultivated. Irrigation in Chambal catchment area has led to a drastic change in the crop cultivated, millets giving way to wheat, cotton and sugarcane. This was after irrigation was begun in the area.

Drawbacks:

The soil texture is coarser here compared to other regions and there is low plant available water capacity (water availability for plants is low). Drainage conditions have been imperfect resulting in spread of surface and subsurface soil salinity and/or sodicity in some places. The groundwater has been overexploited as well and this has led to a drop in groundwater resources.

ASERs:

- a. **North Punjab Plain**, Ganga-Yamuna Doab and Rajasthan uplands; deep loamy alluvium-derived soils (occasional saline and sodic phases); LGP is 90-120 days.
- b. **North Gujarat Plain**, including the Aravalli range and east Rajasthan uplands: deep loamy grey brown and alluvium derived soils (including sodic phase); LGP is 90-120 days.
- c. **The Ganga-Yamuna doab**, Rohilkhand and Avadh Plain: deep, loamy alluvium-derived soils (sodic phase included); LGP is 120-150 days.
- d. **The Madhya Bharat Plateau and Bundelkhand Uplands**: deep loamy and clayey mixed red and black soils; LGP is 90-120 days.

5. Hot semi-arid eco-region with medium and deep black soils:

The eco-region occupies an area of 17.6 m ha (5.4 per cent of the entire geographical area of India) which covers the central highlands (Malwa), the plains of Gujarat, Kathiawar peninsula, western areas of Madhya Pradesh, and south-eastern parts of Gujarat and Rajasthan.

Agro-Climatic:

The region experiences hot and wet summers and dry winters. The annual precipitation of 500-1000 mm caters to 40-50 per cent of the annual PET demand (1600-2000 mm). So there is a gross water deficit annually amounting to 800-1200 mm. The LGP is 90-150 days in a year. The dominant soil moisture regime in the region is typic-ustic and the soil temperature regime is hyperthermic and isohyperthermic. The region is a drought-prone area owing to parts of Banswara in Rajasthan, Jhabua and Dhar in Madhya Pradesh and Panchmahal, Bhavnagar and Amreli in Gujarat being open to drought hazard every three years.

Soils:

Gently to very gently sloping deep, loamy to clayey soil and nearly level to very gently sloping deep black soils are the dominant types. Clayey, slightly alkaline, calcareous soils with swell-shrink properties typify the Malwa plateau soil.

Use of Land:

Dry deciduous forest makes up the natural vegetation. Dryland farming results in growth of sorghum, (kharif and rabi), pearl millet, pigeonpea, groundnut, soybean, maize and pulses (kharif crops) and safflower, sunflower and gram (rabi crops). Wheat is cultivated after irrigation of land.

Drawbacks:

The intermittent dry spells of weather are a worry. Imperfect drainage limits optimum root ramification and availability of oxygen in areas that lie low. Irrigated agriculture faces soil salinity and alkalinity hazards. Severe salinity and sea water inundation, a seasonal feature, causes failure of crops in the Kathiawar coastland.

ASERs:

- (a) **Central Kathiawar Peninsula hot, dry semi-arid ESR;** shallow and medium loamy to clayey black soils (deep black soils as inclusion), medium available water capacity (AWC).
- (b) **Madhya Bharat Plateau, Western Malwa Plateau, Eastern Gujarat plain, Vindhyan and Satpura ranges and Narmada Valley:** hot, moist semiarid ESR; deep, clayey black soils (shallow black soils as inclusion); medium to high AWC.
- (c) **Coastal Kathiawar Peninsula:** hot, moist semiarid ESR; deep loamy coastal alluvium—derived soils (saline phases as inclusion); low to medium AWC.

6. Hot semi-arid eco-region with shallow and medium (dominant) black soils:

This eco- region has a hot, semi-arid climate. It comprises the Deccan Plateau—most of the central and western parts of Maharashtra, northern parts of Karnataka and western parts of Andhra Pradesh. It is 31.0 m ha in area (9.5 per cent of the geographical area of the country).

Agro-climate:

The summer is hot and humid and the winter is mild and dry. The mean annual precipitation is 600-1000 mm, 40 per cent of the- annual PET demand of 1600-1800 mm (gross annual water deficit—800-1000 mm). The LGP is 90-150 days or even less than 90 days at places. Some parts in Ahmednagar, Bid, Solapur, eastern parts of Sangli, eastern parts of Satara, Osmanabad and Latur in Maharashtra and Bidar, Gulbarga, Bijapur and Dharwad in Karnataka are drought-prone. Severe drought occurs once in three years. The moisture availability is mostly submarginal. The soil moisture regime is ustic and the soil temperature regime is (iso) hyperthermic.

Soils:

Soils are shallow, loamy skeletal and highly calcareous (Pargaon series) and clayey, calcareous and moderately alkaline with swell- shrink properties (Sawargaon and Barsi series).

Use of Land:

Tropical, dry deciduous and thorn forests form the natural vegetation. Rainfed agriculture results in growth of sorghum, pigeonpea and pearl millet (kharif crops). The drought-prone regions have bimodal rainfall distribution; so crops are cultivated during the months of September or October on stored residual soil moisture as the dry period during the first phase of the rains is a long one. Sorghum, safflower and sunflower are grown after the rainy season. Irrigation is necessary for cultivation of cotton and groundnut.

Drawbacks:

The extended dry periods impact on crop growth and crops fail during some years. Soil erosion results owing to high run off during stormy cloud outbursts. There is deficiency of nitrogen, phosphorous and zinc elements that creates nutrient imbalance.

ASERs:

- (a) **South western Maharashtra and North Karnataka Plateau** hot, dry semi-arid GSR; shallow and medium loamy black soils (deep clayey black soils as inclusion); LGP 90-120 days.
- (b) **Central and Western Maharashtra Plateau and North Karnataka Plateau and North Western Telangana Plateau:** hot, moist; semi-arid ESR shallow and medium loamy to clayey black soils (medium land deep clayey black soils as inclusion); LGP- 120-150 days.
- (c) **Eastern Maharashtra Plateau:** hot, moist; semiarid ESR; medium land deep clayey black soils (shallow loamy to clayey black soils as inclusion); LGP 120-150 days.
- (d) **North Sahyadris and Western Karnataka Plateau:** hot, dry subhumid ESR.

7. Hot semi-arid eco-region with red and black soils:

This eco-region has a hot, semi-arid climate. It covers 16.5 m ha in area (5.2 per cent of India's geographical area) spread over the Deccan Plateau (Telangana) and parts of Eastern Ghats in Andhra Pradesh.

Agro-climate:

The region has hot and dry summers and mild and dry winters. The mean annual rainfall is 600-1100 mm, 40 per cent of the annual PET demand (gross annual water deficit—700-800 mm). The LGP is 90-150 days.

Drought-prone areas are Nalgonda, Mahbubnagar, Kurnool, Prakasam, Nellore and Cuddapah districts. The soil moisture regime is ustic and the soil temperature regime is isohyperthermic.

Soils:

The soils are moderately to gently sloping red soils which are non-calcareous and neutral in reaction (Patancheru series). Black cotton soils are clayey, calcareous and strongly alkaline in reaction with swell and shrink phenomena on wetting and drying (Kasireddipalli series). They have high production potential as well as enormous management problems.

Use of Land:

Natural vegetation is characterised by tropical, dry deciduous and thorn forests. Rainfed agriculture helps in growth of sorghum, cotton, pigeonpea, rice, groundnut and castor (kharif crops). After the rainy season, sorghum, sunflower, safflower and oilseeds are cultivated on residual soil moisture. Rice is cultivated in the rabi season with irrigation.

Drawbacks:

The high runoff results in erosion of soil and its nutrients. Imperfect drainage and unthoughtful use of water for irrigation has led to subsoil salinity and sodicity particularly in areas that have black soils. Nitrogen, phosphorous and zinc are deficient in soil, resulting in nutrient imbalance. Droughtiness is a frequently occurring feature and it results in crop failure.

ASERs:

- (a) **South Telangana Plateau (Rayalseema) and Eastern Ghat** hot, dry semiarid ESR; medium AWC; LGP—90-120 days.
- (b) **North Telangana Plateau:** hot, moist semiarid ESR; high AWC; LGP-120-150 days.
- (c) **Eastern Ghat (South):** hot, moist semi-arid/ dry sub-humid ESR; medium AWC; LGP—150- 180 days.

8. Hot semi-arid eco-region with red loamy soils:

The eco-region has hot, semi-arid climate and red loamy soils spread over the Eastern Ghats, southern portions of the Deccan Plateau, Tamil Nadu uplands and western portions of Karnataka. It extends over an area of 19.1 m ha, 5.8 per cent of the Indian geographical area.

Agro-climate:

With hot and dry summers and mild winters, the eco-region has an annual rainfall of 600-1000 mm (annual water deficit— 400-700 mm). While the western parts get 70 per cent of the 1-ainfall from June to September; the eastern areas receive rains from October to December. The LGP is 90-150 days. The soil moisture regime is ustic and the soil temperature regime is isohyperthermic.

Soils:

Non-calcareous and slightly acidic soils (Tyamagondalu series) and soils that are calcareous and moderately alkaline in reaction (Palathurai series) are found. Both types of soils are low in cation exchange capacity.

Use of Land:

Tropical, dry deciduous and thorn forests are found in the eco-region. Traditional rainfed agriculture helps in cultivation of millets, pulses and groundnut (kharif season) and sorghum and safflower (rabi season). Irrigation is done to grow mostly rice but also cotton and sugarcane.

Drawbacks:

High runoff leads to heavy soil erosion. The soil texture is low and plant available water capacity is low to medium, with the result that severe droughtiness results in the crop growing period. Deficiency of nitrogen, phosphorous and zinc leads to nutrient imbalance.

ASERs:

- a) **Tamil Nadu uplands and leeward flanks of South Sahyadris** hot, dry semi-arid ESR; loamy to clayey, mixed red and black soils; LGP—90-120 days.
- b) **Central Karnataka Plateau** hot, moist semi- arid ESR; medium to deep red loamy soils; LGP— 120-150 days.
- c) **Tamil Nadu uplands and plains:** hot, moist semi-arid ESR; deep red loamy soils; LGP—120- 150 days.

9. Hot sub-humid (dry) eco-region with alluvium-derived soils:

The eco-region has hot, subhumid (dry) climate. It covers 12.1 m ha, 3.7 per cent of India's geographical area spread over a part of the northern Indo-Gangetic Plain, including Piedmont Plain of the Western Himalayas.

Agro-climate:

Hot summers and cool winters characterise the eco-region. It has an annual rainfall of 1000-1200 mm, almost three-fourths of which is received in the July-September period. The

rains cater to 70 per cent of the annual PET demand which is 1400- 1800 mm (annual water deficit—500-700 mm). The LGP is 150-180 days. The dry period from February to June has a mean annual temperature of over 22 °C. It has ustic soil moisture regime and a hyperthermic soil temperature regime. The parts close to the foothills are relatively cooler and have thermic soil temperature regime. The Gaya district is drought-prone.

Soils:

The soils are generally deep and loamy, and have developed on alluvium. Gently sloping (Basiaram series) and nearly level soils (Shajadapur, Gurudaspur and Itwa series) are neutral in reaction. They have moderate clay and low organic carbon content.

Use of Land:

Tropical dry deciduous forests form the natural vegetation. Both rainfed agriculture and irrigated agriculture are traditionally practised. Rice, maize, barley, pigeonpea and jute (kharif season) and wheat, mustard and lentil (rabi season) are grown. Sugarcane and cotton are cultivated at places under irrigated conditions.

Drawbacks:

Irrigation water is not carefully used which results in water logging and salinity hazards.

ASERs:

- a) **Punjab and Rohilkhand Plains** deep, loamy to clayey alluvium-derived (inclusion of saline and sodic phases) soils; medium AWC, LGP-120-150 days.
- b) **Rohilkhand, Avadh and South Bihar Plains** deep loamy alluvium-derived soils; medium to high AWC; LGP—150-180 days.

10. Hot sub-humid eco-region with red and black soils:

The eco-region has a hot, sub-humid climate. It occupies an area of 22.3 m ha, 5.8 per cent of the country's geographical area. It covers part of Malwa Plateau, Bundelkhand uplands, Narmada valley, Vindhyan scarplands, northern portions of Maharashtra Plateau and some districts of the Madhya Pradesh state.

Agro-climate:

Hot summers and mild winters characterise the region. The precipitation has an increasing trend towards the east direction. The mean annual rainfall is 1000-1500 mm, about four-fifths of the mean annual PET of 1300-1600 mm. The post-rainy phase is fairly dry (February to May) water deficit is around 500-700 mm. The LGP is 150-180 days. The soil moisture regime is typicustic and the soil temperature regime is hyperthermic. In the

relatively more humid districts of Balaghat, Seoni, Mandla, Bhandara and Chhindwara, the LGP is 180-210 days. The Soil Moisture Control Section remains moist for a longer period. This area has udicustic soil moisture regime.

Soils:

Deep black soils are interspersed with patches of red soils. The Marha, Kheri and Linga series, with Kamliakheri series, have calcareous slightly alkaline, montmorillonitic soils with high swell-shrink potential. Red soils that occur on ridges and on pediment surfaces are shallow to moderately deep, clayey, neutral to slightly acidic in nature.

Use of Land:

Tropical moist deciduous forests make up the natural vegetation. Rainfed agriculture is common rice, sorghum, soybean and pigeonpea (kharif crops) and gram, wheat and vegetables (rabi crops) are grown. Unlike rabi, kharif cropping is totally rainfed. Irrigation helps in cultivation of rice, wheat, gram and cotton.

Drawbacks:

The cracking clayey soils have narrow workable moisture. It is difficult to try dry tillage and inter-tillage practices. Crop failure results from risk of inundation of fields during rainy season and risk of acute droughtiness owing to prolonged dry spells in the kharif season. Soil loss happens due to heavy runoff during the rainy season. -Nutrient imbalances occur due to deficiency of nitrogen, phosphorous and zinc.

ASERs:

- (a) **Malwa Plateau, Vindhyan scarpland and Narmada Valley** hot, dry sub-humid ESR, medium and deep clayey black soils (shallow loamy black soils as inclusion); LGP—150-180 days.
- (b) **Satpura and Eastern Maharashtra Plateau** hot, dry sub-humid ESR; shallow and medium loamy to clayey black soils (deep clayey black soils as inclusion); LGP—150-180 days.
- (c) **Vindhyan Scarpland and Bundelkhand Plateau** hot, dry sub-humid ESR; deep loamy to clayey mixed red and black soils.
- (d) **Satpura range and Wainganga Valley** hot, moist sub-humid ESR; shallow to deep loamy to clayey mixed red and black soils; LGP—180-210 days.

11. Hot sub-humid eco-region with red and yellow soils:

The eco-region with hot, sub-humid climate has an area of 14.1 m ha (4.3 per cent of the entire geographical area of India), covering the Chhattisgarh region and southwest highlands of Bihar.

Agro-climate:

Hot summers and cool winters characterise the region. Annual rainfall is 1200- 1600 mm which caters to about 60 per cent of the annual PET demand which is 1400-1500 mm (annual water deficit of 500-700 mm). Some 70- 80 per cent of the rains occur from July to September; PET exceeds the precipitation in October-June period. The soil moisture regime is typicustic (soils being dry from December; to May or June) and the soil temperature regime is hyperthermic (mean annual soil temperature is more than 22 °C). The LGP is 150-180 days in a year.

Soils:

The red and yellow soils are deep, loamy, non-calcareous in nature and neutral-to-slightly acidic in reaction (Ghatapara, Chhal and Ekma series).

Use of Land:

Tropical moist deciduous forests make up the natural vegetation. Traditional farming is rainfed kharif crops like rice, millets, pigeonpea, green gram (moong) and blackgram (urad) and rabi crops like wheat and rice are grown.

Drawbacks:

The soils are affected by severe water erosion. There is partial water logging in early stages of crop growth and seasonal droughtiness in advanced crop growth stage. The available water capacity is reduced by the gravelly-like quality of the subsoil and coarse texture at some places. Nutrient imbalances occur due to deficiency of nitrogen, phosphorous, zinc and boron.

ASER:

- (a) Moderately to gently sloping Chattisgarh/Mahanadi Basin.

12. Hot sub-humid eco-region with red and lateritic soils:

The agro-eco-region has an area of 26.8 m ha (8.2 per cent of India's geographical area) covering the Chhotanagpur Plateau of Bihar, western portions of West Bengal, Dandakaranya and Garhjat hills of the Eastern Ghats of Orissa and Bastar region of Chhattisgarh.

Agro-climate:

Hot summers and cool winters are experienced in this eco-region. Annual rainfall is 1000-1600 mm which covers about 80 per cent of PET demand (annual water deficit of 500-700 mm). A prolonged dry period, of over 90 days in a year, occurs in December-May period. The soil moisture regime is typicustic and the soil temperature regime is hyperthermic (the mean annual soil temperature is over 22 °C). The LGP is from 150-210 days.

Soils:

The red soils (Pusaro, Bhubaneshwar and Chougel series) are fine loamy to clayey, non- calcareous, slightly to moderately acidic and have low cation exchange capacity. Shallow soils are found in ridges and plateaus and deep soils in valleys which are cultivated.

Use of Land:

The natural vegetation is characterised by tropical dry and moist deciduous forests. Rainfed farming helps in growth of kharif crops of rice, pulses and groundnut. Irrigation of fields aids in growing rice and wheat as rabi crops. .

Drawbacks:

Severe erosion of soils, seasonal droughtiness that affects crop yields, low available water capacity due to gravelly-like quality of the subsoil and coarse texture of soil are some constraints. Nutrient imbalances are caused by deficiency of nitrogen, phosphorous, zinc and boron. The red and lateritic soils are subject to moderate to high phosphorous fixation.

ASERs:

- (a) **Garhjat Hills, Dandakaranya and Eastern Ghats** hot, moist sub-humid ESR; deep loamy red and lateritic soils; LGP—180- 210 days.
- (b) **Eastern Ghats:** hot, moist sub-humid ESR; medium to deep loamy red and lateritic soils; LGP—180-210 days.
- (c) **Chhotanagpur Plateau and Garhjat hills** hot, dry subhumid ESR; moderately deep to deep loamy to clayey red and lateritic soils; LGP—150- 180 days.

13. Hot sub-humid (moist) eco-region with alluvium-derived soils:

The agro-eco-region occupies 11.1 m ha of area (3.4 per cent of the entire geographical area of India), comprising north-eastern Uttar Pradesh and northern Bihar including Central Himalayan foothills.

Agro-climate:

The climate is hot and wet in summers and cool and dry in winters. The annual rainfall is 1400-1800 mm which is above the mean annual PET demand of 1300-1500 mm (a small seasonal water deficit of 400-500 mm from February to May). The LGP is 180-210 days annually. The area has udicustic soil moisture regimes. This is because the soil moisture control section (SMCS), as a whole or in parts, remains dry from mid-January to May but in the northern fringe the SMCS does not become dry for 90 or over 90 days annually. The soil temperature regime is hyperthermic as the mean annual soil temperature is over 22 °C.

Soils:

The soils are calcareous and moderately alkaline in reaction (Kesarganj and Sabour series). They reveal different degrees of profile development from A-C soils in the flood plains to A-Bt-C soils on stable terraces. The Tarai soils on piedmont plain on Central Himalayan foothills (Haldi series) are deep, loamy and high in organic matter.

Use of Land:

Tropical moist deciduous and dry deciduous forests dominate natural vegetation. Rainfed agriculture is common with rice, maize, pigeonpea and moong being the kharif crops and wheat, lentil, pet, sesamum and groundnut (with one or two protective irrigations) being rabi crops. Irrigation is made available for growing cash crops like sugarcane, tobacco, chillies, turmeric, coriander and potato.

Drawbacks:

Soil aeration is limited by flooding of land and imperfect drainage conditions. The occurrence of salinity and sodicity has an effect on crop yield. Nutrient imbalances are caused by deficiency of nitrogen, phosphorous and zinc.

ASERs:

- (a) **North Bihar and Avadh Plains** hot dry to moist sub-humid transitional ESR; deep, loamy alluvium-derived soils; low to medium AWC.
- (b) **Foothills of Central Himalayas** warm to hot moist sub-humid ESR; deep loamy to clayey Terai soils; high AWC.

14. Warm sub-humid to humid with inclusion of per-humid eco-region with brown forest and podzolic soils:

The agro-eco-region covers 21.2 m ha in area (6.3 per cent of the entire geographical area of India), comprising Jammu and Kashmir, Himachal Pradesh and north western areas of Uttar Pradesh.

Agro-climate:

Mild summers and cold winters characterise the region. The rainfall is 1000-2000 mm. As the PET demand is low, precipitation exceeds PET in most months. The precipitation shows a rising trend from West to East. There is udic soil moisture regime as the SMCS in many areas does not remain dry for as long as 45 consecutive days or even 90 cumulative days annually. In the extremely western part of the region, there is udicustic soil moisture regime as the SMCS remains dry here for 90-120 days annually. There is Mesic/Thermic soil temperature regime as the mean annual soil temperature varies between 12 °C and 20 °C generally speaking. But the Lahul-Spiti area has cryicmesic soil temperature regime as the mean winter soil temperature goes below the freezing point forming thermal pan for crop growth.

Soils:

The brown forest and podzolic soils are shallow to deep, medium having high organic matter content and weak (A-C) to welldeveloped (A-Bt-C) horizons (Gogji-Pather Wahthora and Kullu series and others). They are fine loamy, neutral in reaction and have 50 per cent or more base saturation. The Tarai soils of the districts of Nainital and Garhwal are deep loamy, neutral to mildly alkaline, moderately base saturated soils rich in organic matter.

Use of Land:

Rainfed agriculture in valleys and on terraces yield wheat, millet, maize and rice. Paddy and horticultural plantation crops like apples are grown on terraced lands. Himalayan moist temperature, subtropical pine and sub-alpine forests comprise the natural vegetation.

Drawbacks:

In northern high altitudes, the choice of crops for cultivation is limited owing to the severe climate—the cryic/frigid temperature regime. Crop choice is also limited owing to imperfect drainage conditions. Soil erosion happens due to deforestation and excessive slopes in the region. Landslide occurs commonly because of soil degradation. There is soil acidity especially in Kangra and Manali, Himachal Pradesh. Droughtiness is a feature in the lower hills and it is a result of excessive runoff and the coarse texture of the soil.

ASERs:

- (a) **South Kashmir and Punjab Himalayas** cold and warm dry/semi-arid sub- humid ESR; shallow to medium deep loamy brown forest and podzolic soils; low to medium AWC; LGP—90-120 days.
- (b) **South Kashmir and Kumaun Himalayas** warm moist to dry sub-humid transitional ESR; medium to deep loamy to clayey brown forest and podzolic soils; medium AWC; LGP—150-210 days.
- (c) **Punjab Himalayas** warm humid to perhumid transitional ESR; shallow to medium deep loamy brown forest and podzolic soils; low to medium AWC; LGP—270-300+ days.
- (d) **Kumaun Hills** Warm humid to perhumid transitional ESR; shallow to medium deep loamy red and yellow soils; low AWC; LGP—270-300+ days,
- (e) **Foothills of Kumaun Himalayas (subdued)** warm moist subhumid ESR; medium to deep, loamy arai soils; medium AWC; LGP—270-300 days.

15. Hot sub-humid (moist) to humid (inclusion of perhumid) eco-region with alluvium-derived soils:

Occupying an area of 12.1 m ha (3.7 per cent of India's geographical area), the agro-eco-region covers the plains of the Brahmaputra and the Ganga river, that is, parts of Assam and West Bengal states.

Agro-climate:

The climate is hot in summers and mild to moderately cool in winters. The rainfall is 1400-1600 mm in Ganga Plain ranges and 1800-2000 mm in Barak Basin (Tripura Plain) and the Teesta-Brahmaputra plains. The precipitation is much above the PET demand in June-October period, which is followed by a period of utilisation till mid-February in most years. The intensity of precipitation shows an increase in northern and eastern (not the southern) parts of the eco-region. The soil moisture regime is udic- ustic to udic: the SMCS remains partly dry for even 90 cumulative days but in Teesta Valley, Barak Brahmaputra Valley and Kushiara Valley (Tripura Plain), the SMCS does not remain dry for as much as 90 cumulative days. The soil temperature regime is hyperthermic. The LGP is over 210 days annually.

Soils:

The soils are slight to strongly acidic and generally have low to moderate base saturation (Jaihing, Kanagarh and Jorhat series).

Use of Land:

Tropical moist and dry deciduous forests mark the natural vegetation. The rice- based cropping system in the Brahmaputra, Teesta and Ganga plains is due to the high rainfall in these areas. The main crops are rice and jute under rainfed conditions. Plantation crops like tea and horticultural crops like pineapple, citrus and banana are cultivated in the northern foothills of the Eastern Himalayas—Teesta and Brahmaputra regions. The stored/residual soil moisture is made use of to grow rice, jute, pulses and oilseeds in the rabi season. With the help of irrigation, rice, wheat and sugarcane are grown as rabi crops in Ganga and Teesta plains.

Drawbacks:

Flooding and waterlogging is a problem. Excessive leaching of bases and nutrients has resulted in low base status soils especially in the Brahmaputra plain. There are nutrient imbalances due to soil acidity.

ASERs:

- a) **Bengal basin and North Bihar Plain:** hot moist sub-humid ESR; LGP—210-240 days.
- b) **Middle Brahmaputra plain:** hot humid ESR; LGP—240-270 days.
- c) **Teesta, lower Brahmaputra plain and Barak Valley:** hot moist humid to perhumid ESR; LGP— 270-300 days,
- d) **Upper Brahmaputra plain:** warm to hot perhumid ESR; LGP—300 days.

16. Warm sub-humid eco-region with brown and red hill soils:

The agro-eco-region occupies 9.6 m ha (2.9 per cent of the total geographical area of India), covering the northern hilly parts of West Bengal, northern parts of Assam, Arunachal Pradesh and Sikkim.

Agro-climate:

Warm summers and cool winters characterise the region. The annual rainfall is 2000 mm. There are short periods of water stress after the rainy period owing to seasonal water deficit. The LGP is over 270 days in a year. The region has udic soil moisture regime. The severe heterogeneity of elevations in the region has resulted in much variation in solar isolation, PET and soil temperature regimes in the region. The soil temperature regime is thermic at an elevation of >1500 m; it is mesic at an elevation of >3000 m (in many parts of Darjeeling, Sikkim Himalayas and Arunachal Pradesh); it is hyperthermic soil temperature regime in valleys.

Soils:

The soils mostly vary from shallow to moderately shallow and are loamy, brown forest to deep, rich in organic matter with moderate to low base status. The soils of Germotali series are moderately acid and have about 50 per cent bases in the exchange complex.

Use of Land:

Sub-tropical pine forests and temperate wet evergreen forests comprise the natural vegetation. Traditional farming is jhum cultivation which is practised with mixed cropping on the steep slopes under rainfed at an interval of three-four years. Millets are also cultivated traditionally on upland terraces and potato, maize, millets and paddy are grown in valleys. Both rainfed and irrigated agriculture is practised to grow rice, maize, millets, potato, sweet potato, sesamum and pulses in the lower valleys, and at other places, cotton, mesta and sugarcane. Vegetables and plantation crops are grown on hilly lands and medicinal plants and horticultural plants like pineapple, citrus, apple, pear, peach and banana on terraced lands.

Drawbacks:

The severe climatic conditions restrict crop choice, particularly the excessive moisture that leads to water stagnation in valleys after the rainy season. The steeply sloping landforms lead to heavy runoff and severe erosion. The soil is also degraded by deforestation for shifting cultivation. Due to high rainfall, there is intense leaching and soils are rendered with poor base status. After heavy rainfall, there is low temperature which limits growth of second arable crops. Mono-cropping is practised commonly in the region.

ASERs:

- a) **Foothills of Eastern Himalayas (Bhutan foothills):** loamy skeletal to loamy Terai soils.
- b) **Darjeeling and Sikkim Himalayas:** shallow to medium deep loamy brown and red hill soils.
- c) **Arunachal Pradesh (Subdued Eastern Himalayas)** deep, loamy to clayey red loamy soils.

17. Warm Perhumid eco-region with red and lateritic soils:

The region, covering the north eastern hills (Purvachal) and the states of Nagaland, Meghalaya, Manipur, Mizoram and the southern parts of Tripura, occupies 10.6 m ha (3.3 per cent of the total geographical area of India).

Agro-climate:

Warm summers and cool winters characterise the region. The annual precipitation is between 2000 and 3000 mm which is mostly above the PET. The moisture index is above 100 per cent with the result that the eco-sub-region is perhumid. The water deficit is only 100-150 mm after monsoons. LGP is over 270 days in a year. The soil moisture regime is udic and the soil temperature regime is hyperthermic (in valleys) or thermic (in higher topographic areas).

Soils:

The soils are shallow to very deep, loamy, red and lateritic and red and yellow soils. Soils of Dialong series are acidic in reaction and have moderate bases on the exchange complex.

Use of Land:

Wet evergreen and tropical moist deciduous forests are to be found in the region. Traditional farming involves jhum cultivation. Rice is the dominant crop grown in valleys. Rice, millets, maize and potatoes as well as plantation crops (tea, coffee, rubber) and horticultural crops (oranges, pineapple) are cultivated on terraces of hills. Rains help in cultivation of rice and jute in particular. Once the rainy period is over, oilseeds (mustard) and pulses like blackgram, greengram and lentil are grown.

Drawbacks:

Severe soil erosion is a result of deforestation and shifting agriculture. Too much of rains lead to leaching and therefore loss of nutrients from soils. After the rainy period, there is a low temperature which means that a number of crops cannot be cultivated. The people have small to marginal land holdings and so, modern agricultural implements cannot be introduced.

ASERs:

- a) **Meghalaya Plateau and Nagaland Hill:** medium to deep loamy to clayey red and lateritic soils; medium AWC; LGP—270- 300+ days.
- b) **Purvachal (Eastern Range):** deep loamy red and yellow soils; low to medium AWC; LGP—300 days.

18. Hot sub-humid to semi-arid eco-region with coastal alluvium-derived soils:

The agro- eco-region, spread over the south-eastern coastal plain from Kanyakumari to the Gangetic Delta, has an area of 8.5 m ha (2.6 per cent of India's entire geographical area).

Agro-climate:

The Eastern coast has a range of climatic conditions—semi-arid, sub-humid (moist). A rainfall of 900-1100 mm occurs in the coastal parts between Kanyakumari and South of Thanjavur in Tamil Nadu and between north of Chennai, Tamil Nadu and West Godavari, Andhra Pradesh. The PET here is 1700-1800 mm and so, the annual water deficit is 800-1000 mm. The LGP is 90-150 days. The eastern coast between Nagapattinam and Chennai and up to north-western part of the coastal strip, including parts of Andhra Pradesh, Orissa and West Bengal, experiences 1200-1600 mm rainfall, four-fifths of the rains received from June to September. The PET is between 1400 and 1700 mm (annual water deficit is 600-800 mm). The LGP varies from 150 to 210 days or more annually. The soil temperature regime is isohyperthermic (the mean annual soil temperature is more than 22°C and the difference between mean summer and mean winter soil temperatures is less than 5°C).

Soils:

Motto and Kalathur series of soils are slight to moderately sodic and clayey. They are different in their cation exchange capacity. The Kalathur soils have high swell-shrink potential.

Use of Land:

Rice is dominantly cultivated in kharif and rabi seasons. Coconut is the leading plantation crop grown. Pulses (blackgram and lentil) and oilseed crops (sunflower and groundnut) are grown after rice on residual moisture in the soil. Raising of coastal and brackish water fisheries is a major economic activity.

Drawbacks:

The drainage conditions are imperfect and availability of oxygen is limited which affect crop yield. Poor drainage also leads to soil salinity and sodicity which have an impact on crop production. Cyclones during monsoon and retreating monsoon periods may be devastating.

AESRs:

- (a) **South Tamil Nadu (coastal):** hot dry semi-arid ESR; medium AWC; LGP—90-120 days.

- (b) **North Tamil Nadu plains (coastal):** hot moist semi-arid ESR; high AWC; LGP—120-150 days.
- (c) **Andhra Plain:** hot dry sub-humid ESR; low to medium AWC; LGP—150-180 days.
- (d) **Utkal plain and East Godavari delta:** hot dry sub-humid ESR; medium AWC; LGP—180- 210 days.
- (e) **Gangetic delta** hot moist sub-humid to humid ESR; medium AWC; LGP—240-270 days.

19. Hot humid perhumid eco-region with red, lateritic and alluvium-derived soils:

Comprising Sahayadris, western coastal plains of Maharashtra, Karnataka and Kerala and Nilgiri Hills of Tamil Nadu, the eco-region occupies 11.1 m ha (3.6 per cent of India's total geographical area).

Agro-climate:

Hot and humid summers and warm winters characterise the region. The mean annual temperature is 25°C-28°C. The mean summer and winter soil temperatures have a difference of less than 5°C. The mean annual rainfall is over 2000 mm in most of the parts. It exceeds the PET demand of 1400-1600 mm but there is seasonal deficit of 300-400 mm in the months of February and March and in the first half of April. The LGP ranges from 150 to 210 days and it may exceed 210 in some places. The soil moisture regime is udic and the soil temperature regime is isohyperthermic.

Soils:

Red and laterite soils dominate along the leeward flank of Sahayadris and alluvium-derived soils in the coastal plains. The soils of Thiruvananthapuram and Kunnammangalam series are deep, clayey, strongly to moderately acidic and poor in base saturation. The soils are low in retentive capacity and inherent fertility.

Use of Land:

Tropical moist deciduous forests can be seen in the region. Rice, tapioca, coconut and spices are cultivated in plenty.

Drawbacks:

Too much of leaching results in plant nutrients and bases getting depleted. Waterlogging has an adverse impact on crop growth in plains in the coastal areas. Steep slopes cause runoff and soil is eroded. Inundation of land is responsible for creating localised saline marshes.

ASERs:

- (a) **North Sahyadris and Konkan Coast:** hot humid ESR; medium to deep loamy to clayey mixed red and black soils; medium to high AWC; LGP—210-240 days.
- (b) **Central and South Sahyadris** hot, moist sub-humid to humid transitional ESR; deep loamy to clayey red and lateritic soils; low to medium AWC; LGP—210-270 days.
- (c) **Konkan, Karnataka and Kerala coastal plain** hot humid to perhumid transitional ESR; deep, clayey to loamy acidic coastal alluvium- derived soils; low AWC; LGP—240-270 days.

20. Hot humid per-humid Island eco-region with red loamy and sandy soils:

The eco-region comprises the Andaman and Nicobar Islands in the east and Lakshadweep in the west. It occupies 0.8 m ha which amounts to 0.3 per cent of the total geographical area of India.

Agro-climate:

Tropical conditions are found, with the mean summer and mean winter temperatures differing by little. The annual rainfall in Andaman and Nicobar is 3000 mm and that in Lakshadweep Islands is 1600 mm. The rainfall fully covers the PET demand except for a seasonal water deficit of 300-400 mm after the monsoon period (January-March). The LGP is more than 210 days. The soil moisture regime is udic and the soil temperature regime is isohyperthermic.

Soils:

Soils of the Andaman and Nicobar Islands are medium to very deep, red loamy including marine alluvium-derived soils along the coast. The soils of Ahargaon, Dhanikhari and Garucharma series are slightly to strongly acidic and moderate to low (40- 70 per cent) in base saturation. The soils of Lakshadweep Islands are highly calcareous and sandy.

Use of Land:

Tropical rain (evergreen) and littoral and swamp forests dominate. Two-thirds of Andaman is under forest cover. Rice is the dominant crop grown. Plantation crops are grown which include coconut, arecanut, oil palm, tapioca and pepper. In Lakshadweep, rice is grown under lowland conditions. The main plantation crop is coconut. Marine fishery is an important occupation of the people.

Drawbacks:

The tropical rainforest ecosystem has been degraded, leading to heavy soil erosion. There is the need to introduce' sustainable plantation crops (oilpalm) to ensure maintaining of the ecosystem. Inundation of coastal lands has led to saline marshes and formation of acid

sulphate soils. There has been an increase in areas under mangrove which suggests increase in degradation of coastal lands.

ASERs:

(a) **Andaman and Nicobar group of islands:** hot perhumid ESR; shallow to medium deep, loamy to clayey red and yellow and red loamy soils; LGP—300 days.

Level Lakshadweep and group of islands hot humid ESR; shallow to medium deep loamy to sandy black, sandy and littoral soils; LGP—240- 270 days

Water harvesting - concept, significance, types, methodology

Water harvesting involves very diverse methods of collecting and managing floodwaters and surface runoff. Techniques can be grouped as: micro-catchment water harvesting, macro-catchment water harvesting, floodwater harvesting, rooftop and courtyard water harvesting and groundwater water harvesting.

Water is one of the most essential natural resources that are present on this planet. Water plays a major role on the earth. Water covers more than 70% of the earth's surface. It is essential in human, aquatic, and animal life. Water covers the everyday essentials of humans and comes in free form. About 60 to 70% of the human body covers with water. However, it is a basic ingredient of any living being. According to the Atharva Veda, life is believed to be first evolved and nourished in water. The Rig Veda says water has a lifesaving medicinal quality, so it needs to be conserved. Water is also required in large quantities for different sectors like irrigation, industries, transportation, hydroelectricity plants, and household activities. All extraordinary civilizations began and flourished close to water bodies. In the 21st hundred years, we can never again reject that water is turning out to be increasingly scarcer continuously. Taking into account that water is the key element that empowers all life to make due and flourish, the preservation of water has turned into a significant part of a greener tomorrow. The world requires a minimal expense clean stockpile of water into the indefinite future. Furthermore, there could be no greater way to this than water harvesting. Many regions of the planet are confronting high to outrageous water stresses. This pressure is because of a shortage of underground water, a botch of existing water bodies, expansion in stream water contamination by permitting modern and metropolitan poisons to stream into streams, absence of water reusing, no astute use, and wastage of water. Consequently, there is a need for a shrewd water management system.

Water Harvesting

The term water harvesting alludes to the collection of rainstorms from a catchment to give water to humans, animals, or agriculture use. The water in this manner gathered can either be used right away, with respect to the water system, or be put away in over-the-ground lakes or in subsurface repositories, like storage or shallow springs, for ensuing use. Thusly, water harvesting is an old practice that has empowered a few social orders to stay alive in semiarid and dry regions that were meager or inaccessible.

Major Sources for Rainwater Harvesting

1. Roofs: Buildings with impenetrable rooftops give viable water for different purposes.
2. Cleared and Unpaved Areas: Landscapes, open fields, parks, storm water channels, streets, and other open regions can be actually used to reap the overflow. The primary benefit of involving the ground as a gathering surface is that water can be gathered from a bigger region. This is especially favorable in areas of low precipitation.
3. Water bodies: Lakes, tanks, and canals are valuable stores of water. The collected water cannot exclusively be utilized to meet the water prerequisites of the city; however, it likewise re-energizes groundwater springs.
4. Storm water Drains: Those districts which have a legitimate organization of storm water channels give straightforward and savvy implications for harvesting water.

Water Harvesting can be embraced in various ways

-  Catching overflow from roofs
-  Catching overflow from neighborhood catchments
-  Catching occasional floodwaters from local streams
-  Rationing water through watershed the executives

These methods can fill the accompanying needs

-  Serves drinking water.
-  Serves water for the irrigation system.
-  Increment in groundwater re-energizes.
-  Decrease storm water releases, metropolitan floods, and over-burdening of sewage treatment plants.
-  Decrease seawater entrance in seaside regions.

How an individual can harvest water

An individual or individuals can easily harvest water by using their houses as an advantage of capturing runoff rainwater from rooftops.

1. Rooftops alignment setup: Setups required for the water harvesting system in the house
2. Catchment region/gutter setup: The more the slants of catchment regions, the speedier the overflow and thus quicker assortment of water. The rate should be controlled utilizing plastic sheets, black-top, or tiles alongside slant.

3. Conveyance structures: These designs are the necessary resources to move the gathered water from the catchment surface to the putting away vessels. (Pipelines, valves, etc.)
4. Collection tanks: The gathered water from the catchment region is expected to be gathered and put away in appropriate storage.
5. Filters: To make the gathered water usable, it should be tainting-free, safe, and economical. The accompanying separating framework might be utilized, for example, sand gravel filter, charcoal filter, and PVC pipe filter, and sponge filter.
6. Pumps: A pumping system is required to force collected filter water from the main storage tank to an overhead tank of the house for household purposes.

Component required

- ✓ Rooftop catchment/ gutter setups.
- ✓ Convenient system (PVC pipes, tubes, adjustment valves, diversion valves, sealing balls, etc.)
- ✓ Filtering system.
- ✓ Collection and storage equipment (galvanized tanks, Ferro cement tanks, concrete tanks, etc.)
- ✓ Pumping system.

Tools and other equipment for the construction setup.

Methods of water harvesting

Traditional methods:

1. Kund

In the sandy towns of the Thar Desert, a clever arrangement of water harvesting is known as Kund's or Kundis. Kund is the neighborhood's name given to a covered underground tank, that was grown essentially for handling drinking water issues. The Kund comprises a saucer-molded catchment region with a delicate slant towards the middle where a tank is arranged. Openings or gulfs for water to go into the tank are typically monitored by a wire lattice to forestall the section of drifting flotsam and jetsam, birds, and reptiles. The top is normally covered with a top from where water can be really long with a can. Kunds are all-around round in shape, with little variety between the depth and width which goes from 3-4.5 m.

2. Saza Kuva

An open well with different proprietors, saza kuva is the main wellspring of the water system in the Aravalli slopes in Mewar, eastern Rajasthan. The name saza means to partner. Harva, a man with exceptional abilities in groundwater identification, helps fix the site. Saza

kuva is developed by farmers. The dirt recovered to make the well pit is utilized to develop a tremendous round establishment or a raised stage slanting away from the well. The first is worked to accommodate the rehat, a customary water-lifting gadget; the slanting stage is for the chada, in which bison are utilized to lift water.

3. Bamboo Drip Irrigation

In Meghalaya, one more procedure for the tapping of stream and spring water is pervasive in which bamboo is utilized to water crops. It is amazing to such an extent that around 18-20 liters of water entering the bamboo pipe framework each moment gets shipped north of a few hundred meters lastly gets decreased to 20-80 drops each moment at the site of the plant. The ancestral ranchers of Khasi and Jaintia slopes utilize the 200-year-old framework. The bamboo drip water system is typically used to water the betel leaf or dark pepper crops planted in Arecanut plantations.

4. Pat

Pats are the unique systems designed in the Bhitada village of Madhya Pradesh. This framework was designed on the basis of the landscape to redirect water from quick streaming slope streams into water system channels called pats. The redirection bunds across the stream are made by stacking up stones and afterward fixing them with teak leaves and mud to make them sealed. The pat channel needs to haggle little nullahs that join the stream now and again, and furthermore sheer bluffs prior to arriving at the fields. These segments perpetually washed away during the rainstorm.

Modern methods of water harvesting

1. Surface Water harvesting

The vast majority of the cutting-edge houses have it. It comprises a downpour drain and a seepage pipe associated with it. It helps in gathering in one spot all the water that the top of a house gets. In the event that you don't have it then your rooftop will disperse away from the water and it would become difficult to gather it. Example: Rooftop Rainwater harvesting.

2. Re-energizing Bore wells and Tube wells

The bore wells and tube wells for the most part get re-energized by the underground water. Be that as it may, you can likewise utilize your gathered water to re-energize them. Simply interface the downpour seepage line to a channel that prompts the bore well. It won't just assist you it with willing additionally help individuals around you. The water gathered by the bore wells leaks through holes in its walls and it recharges the groundwater.

3. Ground water recharging

One can expand the level of groundwater by re-energizing strategies. To do this, first, make a pit in the ground, and fill it with sand and rocks. On top of the pit, make a chamber for an assortment of water, which will arrive through the lines of structure housetops. One more method for doing this is to construct a well in the ground and cover it with substantial fronts of fitting thickness so that individuals and vehicles could move without limitation on top. Channelize the water through pipes into the well.

4. Groundwater Dams

The essential rule of the groundwater dam is that water is put away underground other than at the surface. The fundamental benefits of water stockpiling in groundwater dams are that dissipation misfortunes are considerably less for water put away underground. and another advantage is it has less prone to contamination and less raise or entry of parasites. The issue of submergence of land which is typically connected with surface dams is absent with sub-surface dams.

5. Sub-surface Dam

A Sub-surface dam captures or blocks the progression of spring and diminishes the variety of the level of the groundwater table upstream of the dam. It is fabricated completely under the ground.

6. Sand Storage Dam

It is built over the ground. Sand and soil particles shipped during times of high stream are permitted to store behind the dam, and water is put away in these dirt stores. The sand stockpiling dam is developed in layers to permit sand to be kept and better material is washed downstream A groundwater dam can likewise be a mix of these two kinds. While developing a sub-surface dam in a waterway bed, one can build the capacity volume by letting the mass of the Dam ascend over the surface, hence causing extra gathering of silt. Likewise, when a sand-stockpiling dam is built, it is important to exhume a channel in the sand bed to arrive at bedrock, which can be utilized to make a sub-surface dam as well.

7. Rain pod

David L Hote of France developed the rain pod. It permits you to gather water with its novel structure and features. It works like a downpour barrel, the calculated Rain unit gathers water in an enormous tank and, standing taller than a man, has the level and reach to cover a huge region around it, sprinkling the region utilizing only gravity.

8. Lotus Flower system

The framework has been created with the joint effort of Green Cross Italia. its inspiration was taken from a lotus flower. Very much like a lotus blossom, the framework opens its

copper petals during storms and keeps them shut during the other piece of the year to safeguard the virtue of water. The framework can be constructed utilizing nearby materials like cement, copper, and wood.

9. Watree

Watree is a water gathering framework that closely resembles an umbrella flipped around. The framework is intended to be put in clear areas and parks. The framework gathers every one of the valuable drops that fall on it and moves it to tanks situated in an alternate area. During summers when there is a scarcity of water, the capacity tanks can siphon water back through a progression of underground lines.

The advantages of the water harvesting system

- ❖ Less expense.
- ❖ Spending money on water bills can be minimized.
- ❖ Reduces water scarcity.
- ❖ Diminishes the requirement for imported water.
- ❖ Advances in both water and energy protection.
- ❖ Works on the quality and amount of groundwater.
- ❖ Doesn't need filtration for basic and gardening purposes.
- ❖ This innovation is basic, simple to introduce, and work.
- ❖ It lessens soil erosion, rainwater runoff, flooding, and contamination of surface water with composts, pesticides, metals, and different dregs.
- ❖ It is a great source of water for landscape irrigation without adding any chemical substances.

Drawbacks of the water harvesting process

- ✓ Maintenance and upkeep are required.
- ✓ Requires a few specialized abilities for establishment.
- ✓ less and no precipitation can restrict the stockpile of water.
- ✓ If the structure installed is not accurate, it might draw in mosquitoes and other waterborne sicknesses.
- ✓ Storage limits for the storing tanks. During heavy rains and high overflows, it makes problematic.

National Water Harvesters Network

National Water Harvesters Network (NWHN) is a broad organization that tends to water issues through individuals from the different foundations in India and abroad. The individuals from NWHN are principally experts, civil servants, grassroots functionaries,

intrigued residents, and every one of those serious about creating or undertaking a water gathering program. The organization locations and features the neighborhood issues and the conventional frameworks connecting with water gathering to add the reason for local area-based water management.

Objectives of rainwater harvesting

Some of the objectives of rainwater harvesting are:

1. Increment volume of water bodies: During the dry season, there is very little or no downpour. Because of this, the water bodies like lakes, streams, and so on are dried. By utilizing these strategies, the water bodies can be re-energized, and their volume can be expanded.
2. Stopping floods and soil erosion: By putting away water, it decreases the surface overflow. This lessens the surface disintegration. By catching water in repositories, the flood issue in huge rainfalls is likewise lessened.
3. Preventing over-usage of groundwater: Because of the increasing population, the degree of underground water is diminishing quickly. By utilizing rainwater, the usage of groundwater can be decreased.
4. Saving money: Money can be saved on water bills and importing of water. Pumping up underground water is more expensive than that water collection. Thus, the utilization of water sets aside cash.

Importance of water harvesting

Precipitation Pattern and Rain Potential assume a definitive part in storage or re-energizing water in a specific district. The sub-surface geography additionally assumes a significant part in settling on this choice. In some places, the surface is impermeable re-energizing won't be attainable. Thus, it would be ideal to decide on capacity. Where the groundwater is saline or not of consumable guidelines, the substitute framework could be that of storing rainwater. Water harvesting is the strategy of a social affair or aggregating and putting away of water. Water harvesting gives drinking water, homegrown water, water for domesticated animals, water for the little water system,s and a method for expanding groundwater levels.

Water harvesting practices around the world

It has become essential for water specialists across various nations to take on water harvesting and protection procedures.

- ✚ Rooftop rainwater harvesting is ongoing in China and Brazil. Gansu provinces in China and semi-arid northeast Brazil have the undergoing largest rooftop rainwater harvesting projects.
- ✚ In Bermuda, the law requires all new development to incorporate water gathering properly for the occupants.
- ✚ The U.S. Virgin Islands have a comparative regulation.
- ✚ In Senegal/Guinea-Bissau, the houses of the Diola-individuals are continuously equipped with homebrew rainwater harvesters made from nearby, natural bio material.
- ✚ In the UK, water butts are many times tracked down in home grown nurseries to gather water which is then used to water the nursery.

Factors influencing the limit of water harvesting

A few factors assume a crucial part in how much water is harvested. A portion of these factors are:

- ✓ The quantum of spillover.
- ✓ Elements of the catchments.
- ✓ Influence on the climate.
- ✓ Accessibility of the innovation.
- ✓ The limit of the stockpiling tanks.
- ✓ Sorts of the rooftop, its alignment, and its materials.
- ✓ The recurrence, amount, and nature of the precipitation.
- ✓ The speed and simplicity with which the water infiltrates through the soil to re-energize the groundwater.

Type of filters installed in water harvesting system

Filters are very important in the water harvesting systems to make collected water usable and free from other impurities. Some of them are:

1. **Sand filters:** Sand filters are normally the most generally utilized channels. These block brickwork structures. Little stones and sand are filled in this construction to act as a separating medium. Every one of these separating media is made of one channel layer. Every last one of these layers is partitioned utilizing a wired network.
2. **Charcoal filters:** Charcoal filters are drum molded structures. These are topped off with charcoal notwithstanding little stones, significantly smaller gravels, and sand layer by layer. Here additional layers are isolated utilizing a wired network.

3. **PVC filters:** PVC filters are comprised of PVC pipes loaded up with sand and rock isolated by a layer of rock.
4. **Sponge filters:** Sponge filters are the most straightforward and modest water channel. It comprises a PVC drum with a sponge layer halfway. It is proper for house use

Use of harvested water in agriculture to increase water productivity

Water harvesting is based on the efficient harvesting of surface runoff; therefore it requires runoff producing and runoff receiving areas. There are three method of harvesting and recycling of runoff water. In this method harvested water is directed to the main field to irrigate the crop.

Watershed development/management - concept, objectives, characterization, planning, execution, community participation and evaluation; rehabilitation of watershed; PRA; developing economically and ecologically sustainable agro-forestry systems for watershed; case studies

Watershed development/management

In order to understand the concept of watershed, you may go out when it is raining. You would observe that during rains, water flows here and there and eventually follows a particular path. Finally, it gets collected at a particular point (particularly lowest point in your area) depending on the slope. The area which contributes water and flows to the lowest point resembles the watershed. Have you ever observed the flow of rainwater that falls on the roof of your house? The rainwater falling on a roof always flows through a particular outlet (spout). Taking spout as a point/outlet, the area of the roof may be termed as a watershed. If you have separate spouts for different roofs in your house, you may have many small watersheds within your house. The term watershed consists of two words: water and shed. Water occurs in nature mostly in solid, liquid and vapour forms. In watershed, water is considered mainly in liquid form. The word "shed" refers to the roof of a shed which collects rainwater and drains out. Shed thus can be defined as an area well marked by a boundary which receives rainwater and drains out towards a common drainage point or outlet. In the next unit, role of watershed management, its components, major characteristics and criteria for selection of watershed will be dealt with. Integrated watershed management and the importance of institutional arrangement were also highlighted.

DEFINITION OF WATERSHED

Watershed is a topographically delineated area drained by a stream system i.e. the total land area above some point on a stream or river that drains down slope to the lowest point. The watershed is a hydrologic unit often used as physical unit, biological unit and a socio-economic political unit for planning and management of natural resources. Watershed may also be defined as a natural unit of land which collects water and drains through a common point called an outlet by a system of drains. Therefore, watershed is the area encompassing the catchments, command and delta area of a stream. The top most portion of the watershed is known as "ridge" and a line joining the ridge portion along the boundary of the watershed is called as "ridgeline". A watershed is thus a logical unit for planning optimal development of its soil, water and biomass resources.

WATERSHED MANAGEMENT

Watershed management is the process of guiding and organizing use of land and other resources in the watershed to provide desired goods and services without adversely affecting soil, water and other natural resources.

Watershed management in the broader sense means maintaining the equilibrium between elements of natural eco-system or vegetation, land or water on the one hand and human activities on the other hand. The watershed management programmes aim at improving soil health, soil tilth and drainage and achieving efficient use of harvested and stored rainwater for supplemental irrigation and consequently enhanced productivity and higher economic returns. From community development point of view, watershed management programmes aim at controlling flooding, water logging and soil erosion in order to increase agricultural productivity and a more dependable, cleaner water supply for domestic and industrial use. These programmes also help in minimizing risk of floods in rural and urban areas down streams, reducing sedimentation and conserving natural resources efficiently and effectively. Watershed management programmes strive to improve the lot of the entire farming communities rather than focusing on individual farmers only.

Concept of Watershed Management

Watershed management is based on the concept of sustainability and meeting the needs of present population without compromising the interests of future generation. The concept of watershed management is important for the efficient utilization of water and other natural resources. The concept of watershed management may be expressed in symbolic form by "POWER".

- P = Production of food-fodder fuel fruit fibres fish-milk-combine on a sustainable basis.
- = Pollution control.
- = Prevention of floods.
- O = Over exploitation of resources to be minimized by controlling excessive Biotic interferences like over grazing.
- = Operational practicability of all on-farm operations and follow up programmes including easy access to different locations in watershed.
- W = Water storage at convenient locations for different purposes.
- = Wild animal and indigenous plant life conservation at selected places.
- E = Erosion control
- = Eco-system safety
- = Economic stability

- = Employment generation
- R = Rainwater harvesting
- = Recharge of groundwater
- = Reduction of drought hazard
- = Reduction of siltation in multi purpose reservoirs
- = Recreation

POWER is not only important symbolically but watershed programmes bestow real power to the beneficiaries by improving their socio-economic lot.

Benefits of Watershed Management

Watershed management is expected to ensure the following benefits:

1. Controls floods, erosion and sedimentation;
2. Enhances productivity per unit area, per unit time and per unit of water
3. Increases cropping intensity
4. Leads to proper utilization of waste lands through alternate land use systems
5. Ensures ecological balance
6. Maximizes income through integrated farming system
7. Stabilizes income even under unfavourable weather conditions.

Objectives of Watershed Management

The basic objective of watershed management is to overcome the problems of land and water use based on interdependence of all the resources and therefore must be considered together. The watershed ultimately aims, at improving standard of living of common man in the basin by increasing his earning capacity, by providing facilities such as electricity; water for irrigation and drinking water supply, freedom from fear of floods and droughts etc. Watershed management aims at efficient utilization of the entire resources namely soil, water, crop including plantation, livestock, fishery and human population etc. for sustained prosperity of the watersheds. The overall objectives of watershed development programme are outlined below:

1. Recognition of watersheds as a proper unit for utilization and development of all lands.
The land should be treated in accordance with its peculiar need and by methods that will control soil erosion, conserve water, encourage wild life, improve farm income and prevent flood damage to agricultural lands.
2. Retardation and prevention of floods through small multipurpose reservoirs and other water impounding structures at the streams and in problem areas.
3. Provision for an abundant water supply for domestic, industrial and agricultural needs.

4. Minimizing organic, inorganic and soil pollution.
5. Expansion of recreational facilities i.e. picnic and camping sites with more lakes and streams suitable for boating, fishing or swimming.
6. Utilization of natural local resources for improving agriculture and allied occupation or industries (small and cottage industries) to improve socioeconomic conditions of the local residents and minimizing risks during aberrant weather conditions. Improving infrastructural facilities with regard to storage, transportation and marketing of the agricultural produce.
7. Setting up small scale agro industries.
8. Improving the socio-economic status of the farmers.
9. Employment generation.
10. Encouraging people participation.

The above objectives can be achieved by planning and implementing the programme in a systematic way with active participation of farmers including constitution of cooperative watershed management societies. The following guidelines may be followed to achieve the objectives of watershed management.

- ✓ The implementation programme should start from the ridge line of the watershed to the valley and not on piecemeal basis in isolated patches.
- ✓ Development of both arable and non-arable lands should be done together.
- ✓ Forest, pasture, cultivable land and waste lands should be treated as interlinked units of hydrological entity. The condition of all lands use has to be improved to meet the demands of increasing human and animal population.
- ✓ Essentially, all developmental activities are to be carried out on watershed basis-whole watershed area needs to be covered in planned phases. However, treatment of some lands lying outside the watershed, but geographically contiguous can also be taken up based on socio-economic considerations.

Principles of Watershed Management

The main principles of watershed management based on resource conservation, resource generation and resource utilization are:

1. Utilizing the land according to its capability
2. Protecting productive top soil
3. Reducing siltation hazards in storage tanks, reservoirs and lower fertile lands
4. Maintaining adequate vegetation cover on soil surface throughout the year

5. In situ rainwater conservation
6. Safe diversion of excess water to storage points through vegetative waterways
7. Stabilization of gullies by providing checks at specified intervals and thereby increasing groundwater recharge
8. Increasing crop intensity and land equivalent ratio through intercropping and sequence cropping
9. Safe utilization of marginal lands through alternate land use systems with agriculture-horticulture-forestry-pasture systems with varied options and combinations
10. Water harvesting for supplemental and off-season irrigation
11. Maximizing agricultural productivity per unit area per unit time and per unit of water
12. Ensuring sustainability of the eco-system befitting the man-animal-plant -water system
13. Maximizing the combined income from the interrelated and dynamic crop live stock-tree-labour system over years
14. Stabilizing total income.

Watershed Development in India

Watershed activities with respect to hydrological monitoring were initiated in 42 small watersheds located in 8 Centres of Central Soil and Water Conservation Research and Training Institute (CSWCRTI) in 1956. Subsequently watershed based Operational Research Projects (ORPs) were taken up in different parts of the country in 1974, in order to reduce soil loss, increase water availability so as to enhance cropping intensity, agricultural productivity and generate employment. The central and state governments have undertaken various development programmes based on watershed approach as outline below. The Ministry of Rural Development, Government of India is a front runner in these efforts and has implemented special area development programmes for water harvesting.

i) Soil Conservation in Catchment of River Valley Project

The programme was initiated during the Third Five Year Plan to treat catchment area for reducing silt production rate and subsequent siltation of reservoirs, checking soil erosion and consequently improving agricultural productivity. The programme is being implemented in 27 watersheds covering 17 states including Damodar Valley Corporation area. Soil and water conservation measures are also being adopted in critically degraded watersheds ranging between 2,000 and 4,000 ha area.

ii) Integrated Agricultural Development in Drought Prone Areas

Rainfed farming is totally dependent on unreliable and widely variable rainfall resulting in very low agricultural productivity. Monsoon failure further complicates the situation causing unbearable misery and suffering to the people. The Drought Prone Area Programme (DPAP) of Government of India aimed at promoting integrated agricultural development in dry farming regions based on ecologically balanced approach instead of providing temporary relief. The programme also envisaged setting up of productive infrastructure for providing immediate employment in emergencies to the weaker sections. In this programme, a planned methodology in terms of detailed soil survey, hydrological survey and topographic survey was proposed for preparation of the master plan. Based on this, activities such as land use capability classification, installation of wells depending up on existing conditions of the area; water harvesting programmes (construction of tanks or check dams in the catchment areas etc.) were intended.

iii) **Desert Development Programme (DDP)**

The programme was initiated in 1977-78 to control desertification of the desert area by integrating and linking other related state/central programmes and conserve and harness land, water and other natural resources including rainfall for restoration of long term ecological balance. The programme aims at achieving afforestation with special emphasis on sand dune stabilization and shelter belt plantation and grassland development, soil and moisture conservation and. water resources development. This programme fully financed by the central government covered about 36.2 m ha of 131 blocks of 21 districts in five states namely Rajasthan, Haryana, Gujarat (hot arid region), Jammu and Kashmir and Himachal Pradesh (cold arid region).

iv) **Himalayan Watershed Management Project in Uttar Pradesh**

Himalayan watershed management project funded by the World Bank was taken up in 1983 in two watersheds namely Nayar in Garhwal and Panarin Kumaon regions in Uttarakhand covering an area of 2.47 lakh ha. It aimed at minimizing further deterioration of the Himalayan eco-system caused by depletion of forest cover, over grazing, awful land use and careless road construction.

v) **Operational Research Projects on Integrated Watershed Management**

These projects were taken up in 47 watersheds spread over 16 states (Andhra Pradesh, Bihar, Gujarat, Haryana, Madhya Pradesh, Maharashtra, Orissa, Punjab, Himachal Pradesh), Jammu and Kashmir, Kamataka, Kerala, Rajasthan, Tamil Nadu, Uttar Pradesh and West

Bengal) in 1983 covering an area of 35739 ha with the financial assistance of Ministry of Agriculture and Rural Development, Government of India and under the technical guidance of Indian Council of Agricultural Research (ICAR). The projects aimed at developing a programme with people's participation for arresting the deterioration of environment and building up permanent assets in the form of water, sustainable vegetation and improved productivity of cropped land.

vi) **National Watershed Development Programme of Rainfed Agriculture (NWDPA)**

The programme initiated in 1986-87 in the unirrigated arable lands in 25 states mostly had rainfall ranging between 500 and 1125 mm and more. The districts with over 30 % area under irrigation were usually excluded. The programme was restructured in the Eight Five Year Plan in order to achieve sustainable production of bio-mass as well as restoration of ecological balance in the vast rainfed areas of the country. It mainly focused on conservation and utilization of land, water, plant, animal and human resources in a harmonious and integrated manner with low-cost, simple, effective and replicable technology, generation of massive employment and reduction of inequalities between irrigated and rainfed areas. The main activities of the project included:

- a. land and moisture management including optimal cropping system, dry land horticulture, fodder production and farm forestry
- b. contingency seed and planting material stocking
- c. Training, seminars, study tours for staff and farmers within the state/regional! National level
- d. adoptive research trials on different crops in small and marginal farmers land
- e. procurement, fabrication-and supply of survey equipment and prototype implements
- f. Preparation of field manuals and publicity materials.

The programme has been able to achieve the following:

- ✓ Unified command approach of multi-disciplinary team for effective organizational set-up for effective implementation of watershed development programmes
- ✓ Increased productivity of different crops in both black and red soil regions' by contour farming
- ✓ Significant in situ moisture conservation, cropping intensity and productivity in different farming systems based on contour vegetative barriers.

vii) Integrated Wasteland Development Programme (IWDP)

The programme initiated in 1989 aimed at developing wastelands on a watershed basis and mainly focused on silvi-pasture and soil moisture conservation on wastelands.

viii) Integrated Watershed Management in the Catchments of Flood Prone Rivers

The programme was undertaken during Fourth Five Year Plan in eight flood prone rivers of Gangetic basin namely, Ajoy, Gomti, Punpun, Roop Naraian, Sahibi, Sone, Upper Ganga and Upper Yamuna covering watershed area of 16.7 million ha spread over the states of Bihar, Haryana, Himachal Pradesh, Madhya Pradesh, Rajasthan, Uttar Pradesh, West Bengal and Union Territory of Delhi. The programme aimed at enhancing ability of the watershed by absorbing large amount of rainwater, reducing erosion and consequent silt load in rivers and thus mitigating the effect of floods in productive plains.

ix) Integrated Watershed Development Project for Hills and Plains

The World Bank projects in Himachal Pradesh, Jammu and Kashmir, Punjab and Haryana covering an area of 1.24 lakh ha aimed at slowing and reversing degradation of the natural environment through the use of appropriate soil and water conservation practices.

x) Integrated Watershed Development Project (Plains)

The World Bank project covering an area of 4.331akh ha in Gujarat, Orissa and Rajasthan aimed at slowing down and reversing ecological degradation in a variety of agro-ecological zones by promoting sustainable and replicable production system.

xi) Other Watershed Management Projects

Internationally funded watershed management projects are also being implemented in the country.

Rehabilitation of watershed

The Watershed Rehabilitation Program (REHAB) helps project sponsors rehabilitate aging dams that are reaching the end of their design life and/or no longer meet federal or state safety criteria or performance standards. Since 1948, NRCS has assisted local sponsors in constructing over 11,850 dams.

Recent large, high severity fires in the United States, coupled with subsequent major hydrological events, have generated renewed interest in the linkage between fire and onsite and downstream effects (fig. 10.1). Fire is a natural and important disturbance mechanism in many ecosystems. However, the intentional human suppression of fires in the Western United States, beginning in the early 1900s, altered natural fire regimes in many areas (Agee 1993). Fire suppression can allow fuel loading and forest floor material to increase, resulting in fires of greater intensity and extent than might have occurred otherwise (Norris 1990). High severity fires are of particular concern because the potential affects on soil productivity, watershed response, and downstream sedimentation often pose threats to human life and property. During severe fire seasons, the USDA Forest Service and other Federal and State land management agencies spend millions of dollars on post fire emergency watershed rehabilitation measures intended to minimize flood runoff, onsite erosion, and offsite sedimentation and hydrologic damage. Increased erosion and flooding are certainly the most visible and dramatic impacts of fire apart from the consumption of vegetation.

The key to arresting current degradation of upland catchment areas lies in enabling farmers to establish appropriate farming practices combined with physical measures to check erosion and flooding. Reforestation is, in many situations, only a partial solution.

Farming practices

Watershed projects deal with people. Investment in flood control structures, reforestation, or soil conservation work will, in themselves, achieve little unless the farmers and herders residing in the upland catchment area are given the means to move away from ecologically destructive shifting cultivation. This practice involves Afforestation on the banks of the Maithon Dam, India. felling forests over a very wide area and then cultivating for short periods, frequently without regard to topography or fragility of soil. Once settled in more stable communities, the people can adopt more intensive, sustainable farming systems. So investments in conservation have to be matched-and often exceeded-by substantial investments in improvements in farming practices and inputs, social services, and marketing

systems. Probably one of the most difficult aspects of designing watershed projects is how to achieve in practice this balance between giving small farmers the maximum opportunity to improve their incomes while arresting high rates of soil erosion. In establishing appropriate farming systems for these areas, one of the main problems is frequently that excessive numbers of livestock are kept on the land. A strategy to reduce the density of livestock would aim primarily to improve the draught power and milk production of fewer and better quality animals. This can be achieved in several ways: by improving the quality of fodder produced, by encouraging stall feeding, by introducing improved animals, and by providing effective marketing systems. Fodder development, for instance, may involve a variety of activities. Communal grazing lands, grasslands, and degraded forest lands may need to be closed temporarily to allow natural grasses to regenerate and to permit planting of fodder trees, such as acacias to feed goats. Annual fodder species (like winter oats or legumes) may be introduced as a second rotational crop in permanent cropping areas. Fodder trees, pasture grasses, and legumes may be planted on "bunds" (earthen levees), on risers of terraced farmlands, near houses, and in other marginal land spots. Livestock exchange programs could be established to encourage farmers to improve the productivity of their cattle by trading surplus bullocks and low-grade cows for improved breeds. Such measures are an integral component of the Kandi Watershed project in India, which builds on successful small-scale programs already initiated by the Government. Where a high proportion of the population in the catchment area is dependent on crop-based agriculture, the productivity of the land can be increased by improved cultivation practices. These may include plowing on the contour, preparing smoother seedbeds, sowing seeds in time on the contours, increasing plant cover, and using improved seed, fertilizers, and pesticides. On steep slopes where sheet erosion has to be arrested, farmers can be encouraged to plant fruit trees on the contour, to mulch them, and to interplant trees with legumes and pulses. In some places, fodder tree farming, bamboo plantations, or grasses, such as bhabhar grass, might be more appropriate. (Such activities can, in many situations, be undertaken by paid, landless labor.) This will reduce the likelihood of extending food crop production on steep, erosion-prone slopes. The key to securing people's participation in such programs lies in designing broad strategies based on a better understanding of their perceived needs and priorities and in particular of local land tenure and rights regarding the use of land. This implies that enough time has to be spent on sociological studies in order to define the type of incentives needed to elicit farmers' cooperation. The Hazara project in Pakistan, for example, includes a provision for detailed studies of the sociological issues involved in livestock and ownership. Preliminary results

indicate a far more complex pattern of land tenure and use than was initially anticipated, and the implementation of the project will probably be delayed. Experience has shown that other factors are also important. These may include compensatory payments to farmers excluded from upland grazing areas; the timely provision of inputs such as improved seeds, fertilizer, and credit; the construction of improved access roads and feeder tracks; and the provision of social services—such as improved water supplies, schools, and health clinics. The Bank financed Northern Agriculture Development Project in Thailand provides a good illustration of this approach. While 25 per cent of the total project cost was allocated to soil conservation and reforestation, 44 per cent of the total investment went to the project has reduced farmers' dependence on shifting cultivation, which should lead to more effective protection of the remaining forests. The regulation of upland grazing and voluntary closure of rangelands, in particular, may frequently run up against sociological and religious attitudes, especially in Africa and Asia, which result in excess livestock being maintained relative to the carrying capacity of the land. Time is needed to change these. Experience with improving ranching practices also shows that herders need a clear demonstration that it is more profitable to keep fewer but better livestock. This may mean establishing more effective marketing systems or providing attractive savings mechanisms. Improved marketing systems introduced in Kenya in the 1960s successfully reduced stock pressure on marginal land in the Baringo and Isiolo districts of the northern region. Other elements contributing to the success of the scheme were the existence of stock routes (which minimize the risk of spreading disease), holding grounds to fatten the cattle, well-organized slaughterhouses, and meat marketing outlets.

Participatory Rural Appraisal (PRA) Approach for watershed management

The participatory rural appraisal (PRA) or participatory learning and action (PLA) of the field workers use of participatory approaches. Participatory watershed management has emerged as a new pattern for sustainable rural livelihoods and it occupied the central-stage of rural development in the fragile and semiarid environments of the developing nations. The concept of participatory watershed management emphasizes an inter-disciplinary, inter-sectoral and multi institutional mechanism (Rhoades and Elliot2000). Participatory watershed management has been defined as a process which aims to create a self-supporting system, which is essential for sustainability. Participatory watershed management provides opportunities to the stakeholders to jointly negotiate their interests, set priorities, evaluate opportunities, implement and monitor the outcomes. This concept came widely into practice in late 1980s and over the time peoples' institutions, like zila parishads (district revenue administrative units), self-help groups, and watershed-implementing committees were gradually involved in the project management system. With allocation of more funds for watershed development, several non-governmental organizations came forward to aggressively participate in implementing the watershed programs The PRA continues to evolve so fast that no definitions can be final and has to be updated several times. PRA is defined and updated several times by different researchers and few of them are given below: Participatory Rural Appraisal (PRA) is being used to describe a growing family of approaches and methods to enable local people to share, enhance and analyse their knowledge of life and conditions, to plan and to act (Mascarenhas et al., 1991).PRA is based on village experiences in situations where communities effectively manage their natural resources (Cavestro,2003)Participatory Rural Appraisal (PRA) is a process of understanding people, their resources, their socio-economic conditions and a process of exploring their problems, their aspirations and potentials in partnership with people themselves. PRA is an integral component of watershed management. A PRA is defined as an intensive, systematic but semi-structured learning experience carried out in a community by multidisciplinary team which includes community member.

PRA has been described as a growing family approach and methods to enable local people to express, share and analyse their knowledge of life and conditions to plan and act(Chambers, 1994).PRA is a label given to a growing family of participatory approaches

and methods that emphasize local knowledge and enable local people to make their own appraisal, analysis, and plans (World Bank, 2009).

Evolution of PRA and its development

In the field of rural development, the 1980s could be described as the decade of rapid rural appraisals (RRA). RRAs were referred as study used as a starting point for understanding a local situation; carried out by multidisciplinary team; lasting at least 4 days but not more than 3 weeks; and based on information collected in advance, direct observation and interviews where it is assumed that all relevant questions cannot be identified in advance" with a move from PRA to participatory rural appraisals. The shift from conventional surveys onto rapid rural appraisals (RRA) was based on the realization that RRAs were not very participatory, ("windshield survey"), and the accuracy of the information was low. This led to a shift towards participatory rural appraisals (PRA) with the aim of increasing the involvement of the respondents. PR therefore made much emphasis on "handing over the stick" (as participants drew maps or transects) to symbolize the shift in the control over the process (Chambers, 1994). As the former body of PRA, rapid rural appraisal developed in the 1970s and 1980s in response to the perceived problems of outsiders missing or miscommunication with local people in the context of development work. The purpose of PRA is to enable development practitioners, government officials, and local people to work together to plan context appropriate programs. Chambers (1994) compared the RRA and PRA approaches and is given below in table 1. In India; participatory watershed management has roots in the non-government sector that go back nearly as far as the government programs. The seeds of the participatory watershed management can be traced to a small village called Ralegan siddhi in Maharashtra state of India. Anna Hazare, a local leader was responsible for bringing many social changes in the village particularly soil and water conservation measures besides family planning, a ban on alcohol, protection of non-arable lands against open grazing and felling of trees and voluntary labour for community welfare and other measures which helped in restoring natural resources base of the village. This ultimately led to people participation in watershed management and the evolution of participatory watershed management looking beyond just the biophysical aspects to also focus on social and institutional aspects from a bottom up approach. It is now widely accepted that the communities must participate to enhance the productivity of natural resources in a sustainable fashion (Turton et al., 2009).

Principles of PRA

According to Cavestro (2003) there are five key principles that form the basis of any PRA activity no matter what the objectives or setting:

1. Participation –

PRA relies heavily on participation by the communities, as the technique is designed to enable local people to be involved, not only as sources of information, but as partners with the PRA team in gathering and analysing the information.

2. Flexibility

The combination of techniques that is appropriate in a particular development context will be determined by such variables as the size and skill mix of the PRA team, the time and resources available, and the topic and location of the work.

3. Teamwork

Generally, a PRA is the best conducted by a local team (speaking the local languages) with a few outsiders present, a significant representation of women, and a mix of sector specialists and social scientists, according to the topic.

4. Optimal Ignorance

To be efficient in terms of both time and money, PRA work intends together just enough information to make the necessary recommendations and decisions.

5. Systematic

As PRA-generated data is seldom conducive to statistical analysis (given its largely qualitative nature and relatively small sample size), alternative ways have been developed to ensure the validity and reliability of the findings. These include sampling based on approximate stratification of the community by geographic location or relative wealth, and cross-checking, that issuing a number of techniques to investigate views on a single topic (including through a final community meeting to discuss the findings and correct inconsistencies).

Components of PRA

The three basic components of PRA (Mascarenhas, 1991) have been identified as:

1. Methods
2. Behaviour and Attitudes
3. Sharing

Their significance has been recognized and stressed in that sequence.

A. PRA methods used in watershed management

The first basic to be recognized was participatory methods to facilitate analysis by rural people. Methods have provided a professionally acceptable point of entry, for the spread of PRA (Chambers 1994). There are a set of methods that are currently adopted in watershed management at the community level. These methods include:

1. Semi-structured

Interviewing semi-structured interview is a PRA method that engages villagers in a conversation through a series of guide questions (not structured questionnaire) relevant to the villagers. Important information is generated by talking with villagers about topics that interest them. SSI can be used with individuals, key informants, interest groups or other small groups of villagers (Cavestro, 2003). The process of a semi-structured interview involves the interviewer presenting the context of the study and its objectives to the interviewee or interview group (such as a family or household). The set of questions are prepared but open, allowing the interviewees to express opinions through discussion. Questions are generally simple, with a logical sequence to help the discussion flow. Interview questions should be tested prior to interviews. Training people to conduct a semi-structured interview is important and practice is required to become an effective interviewer. Training needs to address team preparation, interview context, sensitive listening, sensitive questioning, judging responses, recording the interview and self-critical review.

2. Social mapping

Social mapping is a PRA method just that involves the sketching/drawing of houses and other social facilities and infrastructure (i.e. Temple, stores, rice mills, school, pharmacy, trails and roads, water pumps, irrigation and recreation facilities) in a village. These features have usually not been well specified in the village vision setting and village land-use maps. It helps to visualize and situate the location of households and other social facilities/infrastructure in a

village. It serves as a baseline for planning, implementation, monitoring, and evaluation of village development activities (including selection of village organizing strategy).

3. Transect walks

Transect walks was designed to have the community illustrate development workers the physical characteristics of their communities. Transect walks are used to achieve an understanding of the natural resources of a village, their diversity and associated problems, and to assess opportunities. Parameters usually covered include topography, land use and ownership, soil features, vegetation, crops, etc. They are very useful in planning land development interventions and identifying sub-zones for special consideration. If conducted at the beginning, middle and end of the project period (during the same season), they can be used for monitoring and evaluating changes along the particular transect. Transect walks can be used to compare reactions/discussions of different types of stakeholders, such as government officials, NGO team members, the local community, etc. They can provide a good cross-section of information that can be used for specific purposes of verification and appraisal. A participatory transects walk entails taking a walk along a pre-determined route with a group of key informants from the local community, and exploring the geography of the area through their eyes. The walk should take in a cross-section of the area of intervention, covering all the agro ecological zones. For example, this might cover from ridge to valley in a watershed, or straight across a slope if interventions are all roughly at the same elevation. Keystone Foundation, Kotagiri, Tamil Nadu in 2000 conducted a transect walk under 14 tribal areas in Nilgiri hills (NGO Programme, 2005).

4. Spider web diagram

It is highly visual method for analysing the relative importance of, or progress on, different aspects of an intervention, representing each project aspect by one arm of the frame of the web, and ranking its importance from 1–10. The spider web diagram is also called a cobweb diagram, participation wheel or an evaluation wheel. It is a highly visual method for analysing the relative importance of, or progress on, different aspects of an intervention. This exercise can be done to plan projects, but particularly to monitor and evaluate them (NGO Programme, 2005). Each aspect is represented by one arm of the frame of the web, and is graded from 1–10. It is also possible to rank programme /village/group/individual performance during (monitoring) or at the end (evaluation) of a programme. The spider web diagram is a relatively quick and easy tool for comparative impact assessment, providing a visual result to which participants can readily relate. However, it is not so suitable for quantitative estimates, which participants in any case found difficult to judge.

5. Participatory resource mapping

In which a group of participants draw a map of their village, depicting important resources and places; how the area is represented is interesting in itself, as generally aspects of greater importance are portrayed more prominently. The resource map is a tool that helps us to learn about a community and its resource base. The primary concern is not to develop an accurate map but to get useful information about local perceptions of resources. The participants should develop the content of the map according to what is important to them. The objectives of resource map is to learn the villagers' perception of what natural resources are found in the community and how they are used (Cavestro, 2003)

6. Photographic comparison method

Photographic comparison is a simple way to stimulate community discussions on changes in a particular geographical area over a period of time. Such comparisons can be used to consider changes in land use, land cover, land form and water bodies. Photographs can be used to track any major physical changes, but less readily any changes related to people and institutions, particularly with regard to attitudes and approaches. Fully capturing social change requires supplementary information collected through other means, such as group discussions (NGO, 2005).

7. Matrix ranking

It is used to elicit the preferences and opinions of participants with regard to a particular subject; matrix scoring for varieties of a crop provides not only fascinating and useful information and insights, but also good-looking tables with figures. Scientists and others can be so impressed by farmers' criteria, judgments and abilities as demonstrated in matrix scoring that they go on from this method to others, and progressively become more participatory in their approach. Matrix ranking criteria's are used for the rows in a matrix and items for columns, people fill in the boxes for each row. The items are ordered for each of the criteria and people put in piles of stones, seeds for scoring relative values. Ranking exercises are not only relevant with villagers as participants, but often they are also very useful for planners and development practitioners. To work with illiterate farmers, problems have to be symbolized with pictures or objects. Ranking was used to identify the importance of agricultural problems. The problems had been identified in informal interviews during the preparation phase for the workshop.

8. Time line (historical mapping)

Used to gain a historical perspective and to compare changes over a considerable period of time, with various factors being documented; The facilitators meet small groups of villagers

and discuss with them the most important events in the community's past and prepare with the information a historical timeline which serves as the base for further work. It is important to involve different groups of the communities to get their usually different perspectives. The timeline with basic events can be used for focused discussions on problems, social and technological innovations or on communities history of co-operations and activities which helped them to solve in past problems successfully.

9. H form

This is used to rank specific issues and lists both the positive and negative aspects. This helps people to come to a finale by showing both sides of an issue. This method is particularly designed for monitoring and evaluation of programmes. It was developed in Somalia for assisting local people to monitor and evaluate local environmental management. The method can be used for developing indicators, evaluating activities, and to facilitate and record interviews with individuals or group discussions. As described below, it is used with literate participants, but it is also possible to use the tool when not everyone is literate.

10. Wealth ranking

Wealth ranking is a PRA method that determines the economic attributes of households in a village. It shows information on the relative wealth and well-being of households in a village. It helps in determining the social and economic status of households in a village. The information generated by the wealth ranking exercise helps in identifying the poor households in the village. Ranking is done by villagers themselves. It serves as baseline and as an opportunity to identify indicators for planning, implementation, monitoring and evaluation of village development activities. Well-being ranking is an extension of the concept of wealth ranking; the latter largely relates to income and physical assets, whilst well-being also includes more overarching issues like health, access to basic needs, indebtedness, etc In Mongolia that wealth ranking was useful in this context as part of a “hidden agenda” by giving “every appearance of being the kind of hard statistical method” that Mongolian researchers and bureaucrats, like their counterparts in many parts of the world, have been professionally socialized to use and expect.

B. Behaviour and Attitudes

Increasingly in PRA, a second basic came to be seen as the behaviour and attitudes of outsiders. For local people confidently and capably to express their own knowledge, to conduct their own analysis, and to assert their own priorities, outsiders had to step off their pedestals, sit down, “hand over the stick” and listen and learn. Such behaviour conflicts with much normal professional conditioning and self-esteem. In the field, most outsiders find it

difficult to keep quiet, to avoid interrupting, to abstain from criticism, to refrain from putting forward their own ideas. In line with this recognition, field experience training came to stress changes in how outsiders behave. Kumar, a leading trainer in the Indian Government service, placed his main emphasis on behaviour and attitudes. He made the counterintuitive discovery that outsiders with less briefing about the methods were more successful as facilitators than those who were more fully briefed. To tackle the problem of behaviour in the field, Anil Shah, of the Aga Khan Rural Support Programme (India) invented “shoulder tapping” (Shah, 2001) as a corrective. This is a contract between outsiders to tap the shoulder of any colleague who criticizes, asks a leading question, or puts forward his or her own ideas. The most powerful and immediate change in behaviour and attitudes has been through DIY (do-it-yourself). This entails requesting local people to be teachers, while the outsiders are students who are taught to do a local task such as winnowing grain, mudding a wall, thatching, spreading manure, weeding, transplanting, washing clothes, cooking, or fetching wood or water. In a refinement developed by Kamal Kar in India, the outsiders are videoed with subsequent viewing and discussion of a playback both to them and to villagers. The impact can be strong, both personally for outsiders, and in establishing rapport between outsiders and villagers.

C. Sharing

The third basic in the philosophy and practice of PRA came to be recognized as sharing. For practitioners and trainers this has become increasingly a conscious strategy and mode of spread. It has two dimensions: sharing knowledge and sharing experience. Sharing knowledge takes three main forms:

1. Local people share knowledge among themselves, especially through analysis in groups and visual presentations.
2. Local people share that knowledge with outsiders. As a condition for facilitating this process, outsiders restrain themselves from putting forward their own ideas, at least at first, or imposing their own reality.
3. Outsiders themselves share what they learn with each other and with local people.

The sharing of PRA experience has been between individuals, organizations, countries and continents. Some of this has flowed from NGOs in India such as Action Aid, AKRSP, MYRADA, OUTREACH, Seva Bharati, and SPEECH which have established, maintained and disseminated this culture of sharing.

Village camps have been made open to people from other organizations. Quite often, a training camp organized by an NGO has included not just its own staff but also people from other NGOs, from government and from other local communities. Sharing of experience has then been part of the rationale and culture of the camp: beyond the sharing of information by villagers, presenting it to each other and to outsiders, the aim has been sharing among outsiders and between them and villagers of daily experience, food, and sometimes celebration, and sharing among outsiders of learning through self-critical appraisal of process. Some international sharing South-South has been in the same spirit. In early 1992, three Indian NGOs – Action Aid, AKRSP and MYRADA - hosted the first international PRA field workshop to which participants came from 11 other countries of the South.

Developing economically and ecologically sustainable agro-forestry systems for watershed

Watershed management is the meant to containing the deterioration of natural resources for maintaining the ecological balance and sustainable economic development.

Land and water are the two most important natural resources gifted by god to human civilization. Judicious use of land and water resources is the fundamental to growth and sustainable development. The increasing human population as well as livestock population coupled with widespread incidence of poverty is exerting high pressure on Earth limited land and water resources to meet various demands. Over 120 M ha of land has been declared as degraded or problematic soils in India (NRAA 2011). The scarcity of water for agriculture and domestic purpose has been regarded as foremost problem and had resulted in low crop productivity and land degradation. There is substantial potential to narrow down the gap between potential and actual yield by embracing of improved management technologies. Different studies had exposed the appropriate management of rainwater in enhancing the productivity (Wani et al., 2003). The concept of watershed management has evolved to ensure the effective use of both natural and social aspects, therefore watershed development programmes include land, water, vegetation, livestock and human resources as essential components (Sikka et al., 2014). A watershed can simply be defined as any surface area from which rainfall is collected and drained to a common single outlet. Watershed is synonymous with a drainage basin or catchment area. A drainage basin is can involve several towns or regions and even countries (Li et al., 2005). There is not a determined size of a watershed as it may differ from a few hectares to several thousands of hectares of areas. Each watershed has a unique combination of inherent conditions, use and management, and the response to flow and water quality is highly variable and complex. The watershed programme is primarily a land based programme, with primary focus on water status and its main purpose being to enhance agricultural productivity through increased in-situ moisture conservation techniques and protective irrigation for socio-economic development of rural community (Joshi et al., 2005). Watersheds serve as effective natural units to monitor the processes that influence the integrity of the functioning ecosystem. Watersheds are like a patchwork cover over the landscape; they are made of many pieces that fit together to make a whole. Initially, watershed management programs were structure-driven approach for soil conservation and rainwater harvesting, aiming at only some productivity enhancements. This was a

compartmental and top-down contractual approach. This led to less transparency and inequitable benefits among the community members. The rich who could invest in a borewell have harnessed the benefits of the augmented water sources. On the other hand, small and poor landholders comprising about 85-90% of the community could not get any equitable benefit from the conservation measures. As such, these interventions were looked at as the employment opportunities during the project period and people's participation was inadequate. India began to look at the watershed development programs in the 1970s for increasing land controlling land degradation and increasing the productivity of soils and soil fertility improvement. Although that the end of the 1980s the situation changed radically. Initially watershed projects were concentrating on soil and water conservation issues. A decade later, it became apparent that technical and physical works alone would not lead to the desired objectives of watershed development and the social, financial and institutional aspects of rural development must also be taken into account. During 1994, the Ministry of Rural Development (MoRD) of the government developed a group of guidelines for implementing its watershed programmes, which intended to realize the full benefits of watershed work. This progressive policy was essentially people-centered and it incorporated good practice from NGO and government policy, such as awareness raising, bottom-up planning, partnerships with NGOs, and community participation. Watershed management is the integration of appropriate technologies and strategies within the natural boundaries of a watershed or drainage basin for optimum development through conservation, regeneration and judicious utilization of all resources: land, water, animals and human beings. In India there is a lot of indiscriminate use of limited water resources, therefore, urgent need of application of the technology of watershed management to solve its annual problems of droughts and floods. The demand for water exceeds its supply and conflicts sharing water resources are on the rise.