# Annex 3

# An Outline of an Agroecological Classification for Nepal

Agricultural research should be tied to defined production pockets on relevant production problems. Any research conducted without a clear idea of where, or for who, the research is being conducted is a misuse of scarce resources. Given the tremendous variability of the soil and climate resources, recommendation domains should be developed based on a simple open-ended Agroecological Zone Classification and Infrastructural Maps such as described here.

Recommendation domains enable information to be gathered, analysed, prioritised, and transferred in an efficient manner. Information regarding agriculture, livestock, or forestry systems gained in one production pocket will have relevance to other production pockets within the designated zone. Without a systematic classification to focus improved technologies, transfer of information is haphazard. A typology forces the development scientists to look at and describe their research and demonstration areas critically in the early stages of development planning. Information characterising the recommendation domains can be as general or as specific as desired. The more information provided on agroecological and socioeconomic features, the more specific the recommended innovation can be.

Given the tremendous diversity of landscapes and climate in Nepal, it is not surprising that agricultural workers have been slow to develop a comprehensive, yet workable system for classifying agroecological zones. For such a system to be useful it must:

- reflect as nearly as possible the biophysical constraints of importance to agricultural and forestry production in Nepal;
- be simple enough to be readily adopted by the National Planning Commission as a useful tool to focus on optimum land resource development;
- use existing classification systems to the extent possible, so as not to further burden planners, politicians, and technical staff;
- delineate clearly-defined altitudinal zonations that are significant for agricultural, horticultural, and forestry production (local variations in temperature, resulting from changes in aspect, slope and air drainage, are recognised, but not mapped); and
- assist planners in providing justification for natural resource development based on the comparative advantages of specific agricultural production pockets (Carson 1992).

### Inputs Required to Develop an Agroecological Zone Map

*Base Maps 1:250,000 Scale*

1:250,000 base maps were used to show the boundaries of development regions, major rivers, towns, roads, trails, and airports.

*Land Systems' Maps from Land Resource Mapping Project (LRMP)*

1:125,000 LRMP Land System Maps were reduced to 1:250,000 and the Physiographic Region Boundaries separating the *Terai*, Siwaliks, Middle Mountain, High Mountains, and High Himalayas were transferred to the base map. Soil drainage features significant to agricultural development were extracted from land systems' maps for the *Terai* Physiographic Region.

*Land Utilisation Maps (LRMP)*

1:125,000 LRMP Land Utilisation Maps were reduced to 1:250,000 and major blocks of cultivated land in the *Terai*, Siwaliks, Middle Mountains, High Mountains, and High Himalayan Regions were delineated. These included all areas of flat or sloping land and bench terraces. Because of the problems of landscape heterogeneity and mapping scale, these cultivated pockets actually ranged from 25 to 100 per cent cultivated. It can safely be assumed that any other land included in these map units is heavily utilised for grazing, fodder, and firewood collection. These delineated units describe the agricultural production pockets referred to in the text.

*Defining Altitudinal Limits and Climatic Zones*

Altitudinal breaks have been defined that are significant to Agricultural and Forestry Production. These breaks help identify and explain differences in crops, cropping patterns, planting dates, and need for supplemental irrigation. They were drafted on the 1:250,000 base map where agricultural production pockets occurred. The area delineated within these contours represents the major climatic zones significant to agricultural and forestry production (See Figure 3.1). It was difficult to find a consensus on the elevation of the lower and upper limits of any particular altitudinal zone. All of these parameters are controlled by gradient changes and, by definition, gradients do not lend themselves to being classified into discrete zones. Differences in slope, aspect, air drainage, characteristics of soil surface (per cent of stones on the surface) and cloud cover can permit a crop to grow and produce significantly above and below the defined limits. Different varieties have different elevation ranges under which they thrive. These factors could not be mapped on a 1:250,000 scale.

*Defining Criteria in the Terai and Dun Valleys*

In the *Terai* and Dun Valleys, a different set of criteria was used to define the agricultural production pockets. All of the *Terai* and Dun Valleys fall into the Tropical Climate Zone and are capable of producing a similar range of agricultural and forestry crops. There are, however, two major, mappable factors of significance to agricultural development. The first is that large areas of land well-suited to agricultural production are presently under forest which is protected by the Government. Although farmers are theoretically forbidden access to these forests, in practice many displaced hill farmers are illegally felling and clearing the forests at an accelerated rate. The other important biophysical differentiation was made based on soils. The active, recent and sub-recent alluvial plains are characterised by imperfectly to poorly-drained soils and are well suited to rice cultivation. This is in contrast to upland soils that are found on erosional landscapes and that are well drained. During the past, when clearing for agriculture, cultivators restricted themselves to the lowland, imperfectly-drained soils because their first choice was rice-producing lands. Regardless of the use, most agricultural areas depended heavily on adjacent forest areas, and, as forests, were cleared and converted into agricultural uses, forest products - timber, firewood, and fodder-became increasingly rare. Farmers often use livestock dung for cooking fuel and rely much more heavily on crop wastes for fodder. There is also a much greater interest in cultivating fast-growing timber species, *Dalbergia sissoo* and Eucalyptus, on private farm land. These are some of the important features of the *Terai* which are quite different from the situation in the hills. However, forest use dynamics are still important and the future use of the lowland and upland forest areas in the *Terai* and Dun valleys requires careful consideration by the Government.

## Soils

The characteristics of Nepalese soils are described in Chapter II and in Annexes 1 and 2. Soil depth, texture, structure, stability, drainage, macro- and micronutrient fertility, infiltration rate, and permeability are all important when assessing the production potential of a given soil. However, the variability of the above soil characteristics is extreme on any mountain slope and attempting to define homogeneous units based on such soil properties is a futile exercise - particularly when developing maps on the scale of 1:250,000. For this reason, soil properties were not directly used when defining Agroecological Zones.

Within each mapped, physiographic region, however, one finds predictable patterns of bedrock types, saprolite characteristics, soil depth, and mineralogy. Consequently, map units reflect ranges of important soil properties. As an example, *Terai* soils are universally deep, but the water table is a restricting feature on the lower piedmont; soil depth is generally very shallow in the Siwaliks; slopes in the Middle Mountain of less than 30° usually have a minimum depth of 50 cm. There is a much smaller proportion of gently sloping land (and associated deep soils) as one moves from the Middle Mountains through to the High Himalayas. So, although it is not possible to map the extreme variability associated with any one mountain slope on the scale of 1:250,000, it is possible to at least predict the range of characteristics one might encounter. The Agricultural Production Pockets are delineated based on the present occurrence of cultivated land within that map unit. Although there is considerable variability within each pocket area, one

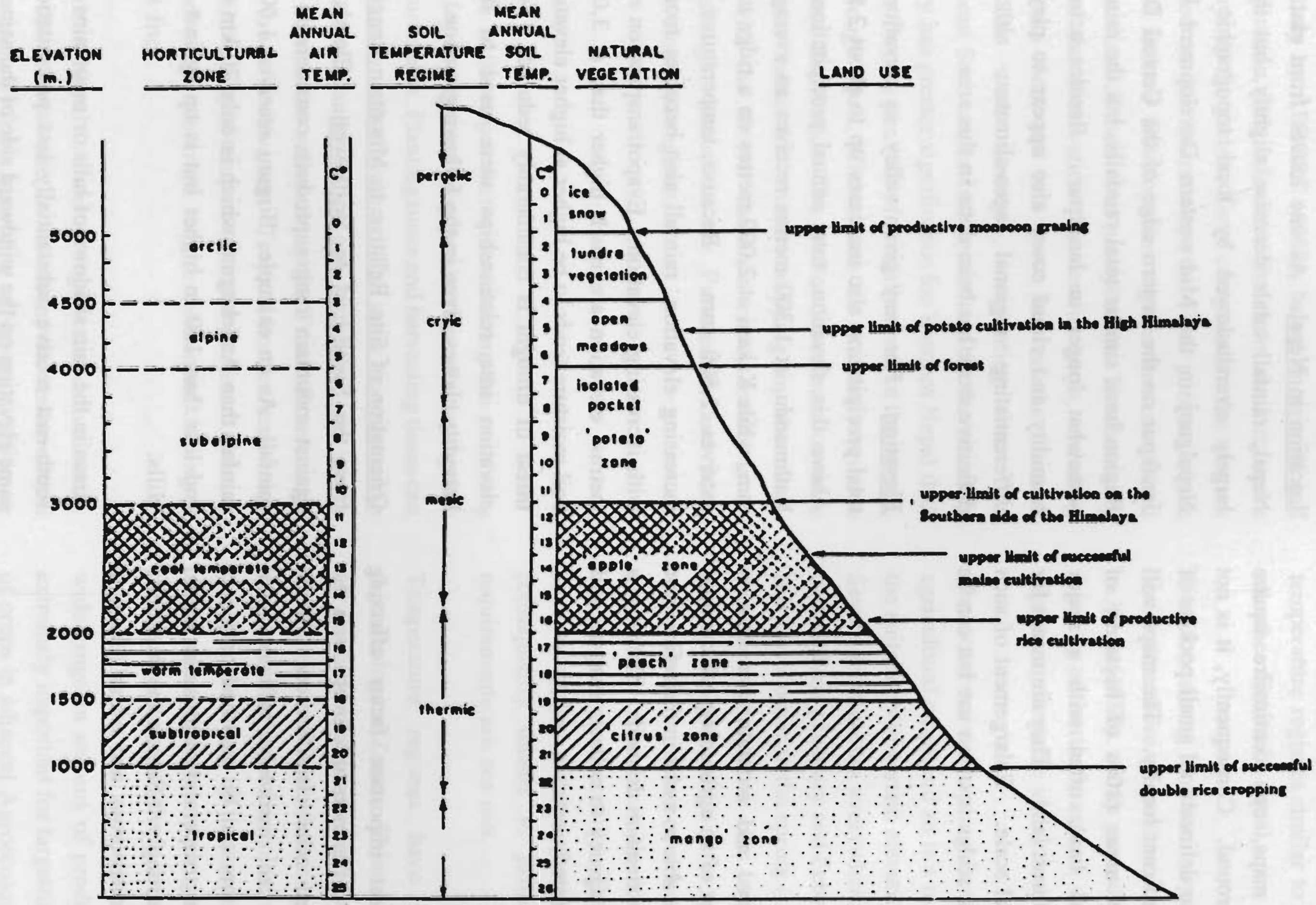


Figure 3.1: Agroecological Zones of Nepal

Source: Horticultural Master Plan, Vol. 3, 1991 can expect that, on average, at least 60 per cent of the mapped unit has soils with characteristics suitable for the production of agricultural crops.

## Scale Considerations

For the 1:250,000 scale maps, one centimetre square represents 625 ha on the ground. Consequently, it is not possible or even desirable to delineate all small pockets of land use that might be significant locally. The maps will only point to large pocket areas (100s of hectares) of intensively-used agricultural land, often with a major component of heavily-used forest land. They are meant for use on a national or regional scale. Enlargement of such maps to 1:20,000 and larger scales is of no use but can be seriously misleading.

## Data Base

The importance of a detailed and accurate data base is essential for the development of an agroecological zonation map. Any new data must be able to assist in the refinement of the overall research and extension domains. There is a great need for some central agency to collect, analyse, and make data available to interested users.

## Climate

Climate is the single most important factor affecting agricultural production and differences in climate form the basis for the agroecological zone classification. While changes in management can markedly influence soil characteristics, climatic factors can be modified only to a small degree. Mean annual temperature and mean annual rainfall as base indicators strongly influence the suitability and performance of individual crops and overall farming systems.

## Precipitation

Precipitation characteristics vary greatly from one area of Nepal to another. The total measured annual precipitation within Nepal ranges from less than 200 mm to over 5,000 mm. Local relief plays an important role in determining the amount of precipitation any area receives. Rainfall isohyet maps based on the scant number of rainfall-recording stations make extrapolation of rainfall dangerous, particularly on a regional level.

### *Country-wide Rainfall Distribution*

Location in Nepal. As one moves from east to west in Nepal, rainfall totals decrease slightly, but this trend is largely overshadowed by local topographic variations. Nepalgunj in the Mid-western Development Region and Janakpur on the eastern edge of the Central Development Region have similar total rainfalls, but the rainy season is somewhat longer in Janakpur. Besides actual rainfall, humidity and cloud cover also appear to play a role in differentiating regional agro-climates; although little definitive work has been done in this area.

Elevation. For any given valley, as elevation increases, total precipitation also increases up to about 2,500 metres. Above this elevation, total annual precipitation decreases. Kathmandu, at 1,300 metres receives an average of 1,200 mm, while Kakani at 2,000 metres on a ridge to the north, receives 2,800 mm. Because temperatures drop with increasing elevation, rainfall also becomes more effective with increasing elevation. Evapotranspiration rates at 500 metres' elevation are much higher than at 3,000 metres. Soil moisture tends to be higher at higher elevations and the threat of drought is considerably reduced. Temperature-elevation inter-relationships were used to develop the humidity classes given in the following section.

Orientation of Site Relative to Mountain Ranges that Run from the South-East to North-west. Clouds forced up against mountain ranges produce considerable orographic rainfall. As an example, Birgunj receives 1,000 mm less rainfall than Amlekhgunj which is only 20 km to the north and less than 100 m higher but is up against the Siwalik Hills.

Areas in the rain shadows of hills or mountains lying to the south-east receive substantially less precipitation than the same elevation on the windward side of the same range. The classic example of effective blocking of rainfall is that 5,000 mm of precipitation falls on the windward side of the Annapurna Massive, whereas only 200 mm falls on the leeward side. These contrasting rainfall patterns occur to a lesser extent on all east-west trending ridges in the country.

Seasonal Rainfall Distribution. In the summer season (between May and October), 80 per cent of the annual precipitation occurs, carried by the east monsoon. While the rainy season begins in Jhapa in mid-May, it is not until two or three weeks later that Kanchanpur receives its first substantial monsoon rains. The rainy season also lasts two or three weeks longer in the east, causing significant differences in agricultural practices between Eastern and Western Nepal. A recent study by APROSC (1989), based on rainfall and evapotranspiration data, calculated that there are forty more growing days in the eastern *Terai* compared to the western *Terai*. Based on this information, the *Terai* portions of the Central and Eastern Development regions are considered humid, regardless of their total precipitation. This humidity accounts for the observation that certain crops, including coconut, areca nuts, and jute grow best on the eastern *Terai*. The west monsoon, originating from the Mediterranean Sea, carries little moisture, but the moisture it does carry has greater significance for Western Nepal than for the east. Twenty per cent of rainfall occurs in the winter, October through April. Winter rains are extremely variable in amount and distribution. The greater dependence on these erratic winter rains for winter cropping in the west, combined with the shorter monsoon rains, results in an increased drought hazard in the Far-western and Mid-western Development regions.

**Temperature**

Temperature is the major factor determining the suitability of an area for any type of crop production. Each crop has certain requirements. Planting times and harvesting times can vary significantly with elevation. The same rice planted in May in the Kathmandu Valley can be planted six weeks earlier just outside the valley along the Trisuli River, some 500 metres lower in elevation. Tropical horticultural crops may be sensitive to cool temperatures and intolerant to frost, whereas cool temperate crops require substantial chilling in order to set fruit.

Temperature in Nepal is most strongly related to altitude. For every 100 metres' rise in elevation, the mean annual temperature drops by 0.5°. According to Nayava (1980) over ninety per cent of the variability of mean annual temperature at recording stations in Nepal can be attributed to elevation alone.

Another factor affecting mean annual temperatures is latitude (for every 3° north of the equator, the mean annual temperature will drop by 1°C). A station at 1,000 metres' elevation in Ilam would have a mean annual temperature one degree centigrade higher than a station at 1,000 metres in Baitadi. While this would not represent a major difference when mapping the agroecological pockets on a scale of 1:250,000, it may be important when extrapolating cropping zones from the Far-western to the Eastern Region of Nepal. Apples growing in Baitadi at 1,900 metres might experience temperature regimes similar to 2,100 metres in Ilam should all other factors be equal.

Sites on strong northern aspects will have temperatures lower than those on southern aspects. In Whiteman's studies in Jumla (1980), winter ground temperatures remained below freezing on northern aspects during the day while southern aspects in the same valley had soil temperatures of +20°C.

The occurrence of spring frosts can seriously affect many agricultural crops and so is a major factor when considering the suitability of certain elevation ranges for sensitive crops. Severe frost occurs everywhere in the country above 1,500 metres during January and February. The later in the season that frosts occur in the spring (i.e., the higher the elevation), the more restrictive the successful flowering of the appropriate range of fruit tree species. Temperate fruit trees also require a certain number of chilling days for fruit production. This limits the lowest elevation at which they can be grown successfully. There are many cases of crops, such as apples, that are grown below 2,000 metres being consequently unable to produce fruit because chilling requirements are not met.

Temperature regimes have been used to define the Agroecological Zones. These zones indicate suitable pockets for production of perennial fruit trees and type and timing of agronomic crops and whole cropping systems. For vegetable crops, such as potatoes, cole crops, and tomatoes, elevation dictates when (not if) the crop can be grown successfully. As an example, potatoes are grown in the the tropical zone during the winter, in the subtropical zone in the spring and fall, and in the cool temperate zone in the summer. This wide range in seasons of production for similar crops is extremely important for targetting gaps on production cycles of crops in adjacent Agroecological Zones.

As one moves to the higher reaches of valleys within the High Himalayas, the maximum elevation at which cultivation can take place increases. For example, potatoes are an important horticultural crop that is grown successfully at 4,200 m in Solokhumbu. Such microclimates are the result of a combination of unique valley alignment, proper slope aspect, and edaphic conditions. Micro-site position becomes increasingly important as one moves to the limits of a particular horticultural crop's range.

## Humidity Classes

Humidity classes have been based on the relationship between mean annual precipitation and mean annual temperature (LRMP 1986). Throughout Nepal, the higher the altitude, the cooler the temperature, and the lower the evapotranspiration. At higher altitudes, then, less rainfall is required to support lush vegetation growth and productive rainfed agriculture. In general, valley bottoms have drier climates than adjacent ridges. Where low elevation valleys project into areas of increasing relief, the valley bottoms become drier. These are described below in the following paragraphs.

### *Semi-arid*

Semi-arid moisture regimes are deep river valleys well within the High Mountains or High Himalayan physiographic region - Thibru in the upper Karnali River valley, and Marpha in the Kali Gandaki occur in the semi-arid regions of Nepal. Juniper and cypress are often associated with these semi-arid regions. The driest areas support caragana and ponicera shrubs. Irrigation is essential for good crop production even during the summer season. Ground crops and temperate fruits do well and represent an important potential export.

### *Sub-humid*

The tropical regions of the Far-western, Mid-western, and Western Development regions fall into the sub-humid moisture regime. The sub-humid moisture regime is also found in sheltered valley bottoms in the rain shadow of the Mahabharat *Lekh.* Here rainfall intensities are especially high.

Jumla, situated in the High Mountains at 2,300 metres, experiences only 770 mm precipitation and so is classed as sub-humid. In these High Mountain regions, rainfed cropping is carried out, but the use of bench terrace systems is less common. Rainfall intensities are much lower and contour terracing can be employed without such serious surface erosion as in other regions. Irrigation permits dry season cropping and improves the yields of monsoon crops.

### *Humid*

Humid moisture regimes are found in the tropical areas of the Central and Eastern Development regions as well as in most of the subtropical and warm temperate zones in the Middle Mountains. These areas are generally highly populated, and two rainfed crops with reasonable yields are expected in most years. Benefits are realised by supplemental irrigation during the dry season. Certain horticultural crops suffer from excessive humidity during the monsoon season.

### *Per-humid*

Per-humid moisture regimes occur in areas receiving significant orographic rainfall, usually in the upper slopes of the Middle Mountains and on the southern slopes of the High Mountain Physiographic Region. Per-humid moisture regimes are expected wherever moisture-laden monsoon winds come in contact with high mountain masses.

Because of poorer agroclimatic conditions (i.e., high humidity and low radiation) these areas are not heavily populated, so settlements and precipitation records are scant. Cropping, when it occurs, is often restricted to potatoes planted on outward sloping terraces. Apple production, where it has been tested in areas such as Daman and Helambu, has serious problems because of the extreme hail hazard and the fungus disease that affects both fruit quality and tree health.

## Other Factors Affecting Climatic Suitability

In addition to these moisture regimes, there are also many features that cannot be mapped on a scale of 1:250,000; but which obviously must be considered when locating sites for horticultural development. Factors affecting the microclimate include those outlined in the following paragraphs.

### *Aspect*

All other factors being equal, southern aspects receive more radiation than northern aspects. The steeper the slopes, the more pronounced is this effect. Whiteman (1980) found that maximum fall autumn temperatures on northern aspect slopes around Jumla were at least 3°C cooler than on the southern aspect slopes. This had a profound effect on evapotranspiration and soil moisture content. It is commonly noted that on east-west oriented ridges, forests occur on the wetter, cooler north-facing slopes, while the southern facing slopes, at the same elevation, are hotter and dryer and support grass or scrub vegetation. Farmers use this knowledge to place crops in full sunshine with a good southern aspect where adequate irrigation water is available. If irrigation is not available, survival may dictate planting trees on cooler, moist north-facing sites. This has been done with apples at the Baitadi Horticultural Farm. Citrus growers in the eastern hills commonly say that mandarins must be planted on slopes facing the Himalayas; probably for the same reason. The Dhankuta Agricultural Station at Paripatle is on a strong south aspect, and consequently, irrigation is essential to ensure citrus tree growth and, production. Aspect effects are extremely important within the High Mountain and High Himalayan Valleys for all agricultural production.

*Air Drainage*

When crops are planted near their absolute limits for production or survival, air drainage can markedly influence the success of horticultural endeavour. Air drainage is often restricted at the bottom of deep valleys, such as those that occur throughout the High Mountains or in shallow basins including Kathmandu and the Dun Valleys. Minimum temperatures tend to fall significantly below what would otherwise be found at that elevation on normal mountain slopes and so restrict certain crop production. Kathmandu at 1,200 m, experiences more frost days than Nagarkot at 2,100 metres. This explains the anomalous findings of the Kirtipur Horticultural Research Station in Kathmandu Valley. Citrus fruits do not grow well in spite of a seemingly appropriate elevation. Fog is usually associated with areas of poor air drainage. Where one finds fog lying in valley bottoms, cooler night temperatures can be expected in the winter. This fog can have a beneficial effect on the moisture regime of crops growing at that time.

*Local Winds*

Winds in mountainous regions are difficult to predict but can strongly influence potential horticultural production. Afternoon winds can have a pronounced cooling effect and so influence temperatures in the area. As an example, the upper Kali Gandaki valley is subjected to severe desiccating winds daily, and windbreaks of rock fences or poplar trees are required to protect sensitive fruit trees. These same constraining winds also occur in certain valleys in Jumla and Dolpa and must be considered when planning the location of fruit orchards. More generally, very strongly gusting pre-monsoon winds occasionally occur, damaging sensitive crops throughout the country.

*Frequency of Hailstorms*

Although the occurrence of individual hailstorms appears as a random phenomenon, there is a correlation between per-humid moisture regimes and increased frequency of hail-storm occurrence. In general one can anticipate 2 hail belts - one along the length of the Mahabharat *Lekh* and the other on the southern slopes of the Himalayas near the border between the Middle and High Mountain Physiographic Zone. This generalisation is further complicated by the fact that in some areas (i.e., south of Pokhara), the Mahabharat *Lekh* is only a low ridge of 1,000 metres. Extremely violent updrafts occur in areas where the low Middle Mountain Regions abut the main Himalayan Front. Syangja district, in particular, is noted for frequent and severe hail storms.

*Rainfall Intensity*

Frequent observations of field conditions after heavy rainfall support the premise that rainfall intensity is highest in the tropical horticultural zone, moderately high in the subtropical zone, moderate in the warm temperate zone, and lowest in the cool temperate zone. Farmers working unterraced slopes at 2,400 metres in Jumla do not have to worry about soil degradation by erosion nearly as much as farmers at 800 metres on similar slopes in Dailekh. Management of intercropped species in the higher rainfall intensity zones will have to ensure that adequate surface protection is given to the soil, so as to reduce potentially severe soil erosion.

**Agroecological and Infrastructural Maps**

Agroecological zone and infrastructural maps provide important basic planning information for the identification of priority programmes throughout the country. These maps give the planner an opportunity to look at both markets and production pockets at the same time. After national priorities are set for overall agricultural development, agroecological maps and infrastructural maps give direction in the setting up of research and extension domains.

## Research and Extension Domains

All of the collected land management information relevant to a specific recommendation domain should be organised into discrete information "portfolios". These "portfolios" will then be used as basic extension materials. As the body of information grows, so will the complexity of the classification system and the recommendation domains. An important task of the Government is to ensure that the classification is appropriate for the various zones within the different districts of Nepal. For example, if agroforestry is to become a major area of interest for enhancing soil fertility, it will be important that the suitability of local and exotic agroforestry species be tied to specific agroecological zones. To the degree possible, refinements should be made to the classification system by recognising changes in cropping patterns, natural forest boundaries, and other features.

Experimental sites must be chosen based on the information that is directly applicable to other sites within the project area. Those sites with the greatest area and largest opportunities for making improvements should be the best represented in research work. The national priority for different agroecological zones should be in proportion to their area. In brief, the Tropical, Subtropical, Warm Temperate, and Cool Temperate Agroecological Zones of Nepal represent 61, 19, 12, and 8 per cent of the arable land in the country.

Tropical, Subtropical, and Warm Temperate Humid Production Pocket Areas within the Middle and High Mountain areas appear to be underrepresented, considering the total area and importance of finding alternative farming systems for traditional hill, grain farmers. There are serious doubts about the extension of research carried out at Khumaltar and Kirtipur to anywhere outside the valley because of the unique climate and soils found there.

The Agroecological Approach provides an effective alternative for streamlining the extension service for the country. It would be based on the field worker's intimate knowledge of the land and farming systems of a particular biophysical zone rather than on being a specialist in a particular commodity or group of commodities. A Junior Technical Assistant (JTA) who has spent 10 years in the Daman area will have considerable difficulty adjusting to the agroclimatic characteristics of Mustang, even though both stations specialise in apples. On the other hand, he may have a wide range of agronomic experience valuable in other cool, temperate per-humid areas of Nepal. Stressing farming systems within the distinct Agroecological Zones provides a basis for the development of useful research and extension packages.