2. REVIEW OF LITERATURE

Sustainable development of any region depends upon the effectiveness of the land use planning process. Land use planning is the systematic assessment of physical, social and economic factors in such a way as to encourage and assist land users in selecting options that increase their productivity, are sustainable and meet the needs of society (FAO 1993). Considering the importance of soil database for land use planning, soil surveys at macro-and micro-levels have been carried out in different parts of the world by various workers since long. This chapter briefly presents the review of the literature on characterization and evaluation of soils with reference to hill agro-ecosystems under the following heads:

2.1 Soil characterization and classification
2.2 Soil fertility mapping
2.3 Land capability classification
2.4 Soil productivity evaluation

2.1 Soil characterization and classification

Soil characteristics and properties are the outcome of the interplay of pedogenic factors and processes prevailing in the area. The hilly and mountainous regions are endowed with a wide range of environmental factors that exert an influence on spatial variability of soils. A review of those factors and processes that have contributed to soil formation is necessary for a better understanding of the wide range of soils.

The hill regions of India extend from Kashmir in the North-West to Arunachal Pradesh in the North-East having a wide range of macro- and micro-climates, physiography, geology and vegetation. Generally, the climate is subtropical at altitudes less than 1,000 m, warm temperate between 1,000 and 2,000 m, cool temperate from 2,000 to 3,000 m and cold temperate from 3,000 to 4,500 m. Physiography of the Himalayan region consists of (i) Greater Himalayas formed largely from metamorphic rocks and valleys of high altitudes,
(ii) Lesser Himalayas composed of a variety of sedimentary and metamorphic rocks and (iii) Outer Himalayas consisting of the Shivalik sedimentary rocks. A large spatial variation in soil forming factors is responsible for evolution of different soil individuals in the hill regions.

The state of Himachal Pradesh is a mountain locked territory in which varied rock formations of Himalayas and Shivaliks constitute the parent materials of soils. Physiographically, the area has been divided into four main regions viz. Greater Himalayas, Lesser Himalayas, Shivaliks and Alluvial plains. Further, there is a wide variation in temperature and rainfall in the state according to location, elevation and aspect which have reflected in the occurrence of variable group of soils.

Hoon (1936) classified the hill soils of Kullu and Kashmir under blue pine as brown earths, under deodar as podzols, under silver fir as grey types and under chir forest as brown earths and immature podzols.

Mukherji and Dass (1942) found four types of soils viz. red loam, brown forest, podzols in Kumaon Hills. They observed that textural character of the profiles depends on the slope gradients. Sandy soils were found mostly along the gradient of 45° or more, whereas, loamy and clay soils were usually found under gentle slopes. In brown forest soils, there was calcification with very little podzolization. Grey brown podzolic soils were acidic than podzols. These soils showed slight illuviation and occurred under well-drained and humid temperate conditions.

Zonn (1950) made a comparison between a natural oak-hornbeam brown soils and a similar soil but under cultivation for over 100 years. There was even distribution of nutrient elements, higher degree of leaching of bases and a lower degree of leaching of P and sesquioxides in a cultivated soil.

Puri and Gupta (1951) observed skeletal, podzolized or old brown earth and brown earth soils in Kullu Himalayas.

Sahi (1961) worked on the two soils, one developed on lime-stone and the other on calcareous shade in Sproon valley, Solan. Both the soils showed the characteristics of brown forest soils or calcimorphic soils. According to 7th Approximation, the two soils were classified as Eutrochrepts.
Yadav (1963), Dhir (1967), Sehgal et al. (1968) and Murthy et al. (1976) observed high amounts of humus and mobile forms of sesiquoxides in Himalayan soils. Illuviation of sesiquoxides and humus was not found significant enough to indicate podzolization in high altitude soils. Further, Kullu soils were characterized by accumulation of organic matter, low base saturation and an altered B horizon. Leaching assumed a dominant role in Himalayan soils leading to the removal of bases. This process was not favourable for the formation of B horizon on steeper slopes and in some soils, to the formation of an argillic horizon in other soils.

Tamhane et al. (1966) revised the soil map of India and attributed the formation of soils largely to parent material. Yadav and Thakur (1972) classified the soils of Himachal Pradesh into the three major soil groups, viz. meadow soils, grey brown podzolic soils and brown forest soils.

Shankranarayana and Hirekerur (1972) classified alluvial soils of Uttar Pradesh and Punjab in accordance with 7th Approximation and observed that soils on highlands belonged to Alfisols and those on recent flood plain to Entisols. Mann and Sharma (1972) carried out a reconnaissance soil survey of eight blocks of Jammu and Kashmir and categorised all the soils into four groups, viz., alluvial soils, brown soils, submontane soils and arid soils.

Sehgal (1973) classified two soils from North-Western Himalayas as Eutrochrepts.

Gupta et al. (1974) studied the properties of forest soils of Kangra district of Himachal Pradesh and classified these pedons as Dystrochrepts, Hapludalfs, Udorthents and Udiluvents. The soils were strongly acid to slightly alkaline, rich in organic carbon and total nitrogen.

Parsons and Harriman (1975) studied on lithosequence in the mountains of south western Oregon of America and reported that soils developed on granite parent rock were low in bases and cation exchange capacity and were without argillic horizon, while those derived from pyroclastic rocks produced profiles with thick argillic horizons and were fine textured and high in bases and cation exchange capacity. Soils developed on schists may or may not have argillic horizon and but have intermediate properties.
Minhas and Karan Singh (1976) classified the soils of Mandi district in Himachal Pradesh as *Typic Udorthents, Typic Eutrochrepts* and *Typic Psammaquents* at a reconnaissance level.

Singh et al. (1977) reported that alluvium derived soils of Sirmour district belonged to *Inceptisols, Entisols, and Alfisols*. However, *Alfisols* were confined to a comparatively smaller area.

Ahuja et al. (1978) classified the soils of Shivalik hills of Haryana into *Eutochrepts and Udorthents*. Govinda Rajan and Gopala Rao (1978) prepared a soil map of India in which soils of Himachal Pradesh and Jammu and Kashmir were classified as brown hill soils & sub-montane soils (Podzolic) and mountain meadow soils, respectively.

Ghabru and Ghosh (1980) studied the two soil profiles of Kangra district in Himachal Pradesh and classified those as *Typic Hapludalfs*.

Verma and Tripathi (1982) categorized the soils of hot, low hill zone zone of Himachal Pradesh as *Typic Ustrochrepts*.

Chakravarty and Barua (1983) classified the soils of hill districts of Assam, which developed on Archaean gneisses, and under varying topographic positions, as *Paleustalf, Hapludult, Paleudult* and *Hapluhumult*.


Pal et al. (1984) reported that soils under conifers and broad leaved tree species within the altitude limits of 1645 to 2250 m in the Darjeeling Himalayan region were rich in humus and mobile forms of sesquioxides.

Gangopadhayay et al. (1986) classified that the soils of Sikkim forest division within an altitudinal range of 1970 and 2425 m as *Typic Hapludults, Mollic Ochraqualf* and *Humic Hapludult*. Sharma and Qaher (1989) studied six protected vis-a-vis eroded Outer Himalayan forest soil profiles and classified all these as Mollisols.

Verma et al. (1990) reported that soils of Kashmir valley are developed mainly with loessic parent material and under sub-humid temperate climate. The organic matter content was found more in the northern aspects with slopes 8-15 per cent due to prevalence of prolonged moist conditions. Walia and
Chamuah (1990) studied four typical pedons representing foot-hill slopes, piedmont (upland and lowland) plains and flood plains in Tirap district of Arunachal Pradesh for their morphology and physicochemical characteristics and classified those as Inceptisols and Ultisols.

Karan Singh et al. (1991) classified the six mid-altitude soil profiles of Outer Himalayas as Alfisols, Inceptisols and Entisols.

Murthy and Sharma (1992) classified the soils of hills of Uttar Pradesh under pine vegetation as Mollisols, Entisols and Inceptisols. They reported that soil structure, horizon thickness, organic carbon content, clay translocation and coatings were largely influenced by aspect, altitude and slope either individually or in combination.


Sharma et al. (1993) characterized the soils of Soan river catchment in lower Shivaliks of Himachal Pradesh for morphological characteristics and physico-chemical properties and classified those as Entisols and Inceptisols.

Kaistha and Gupta (1993) studied the soils of two typical pedons of sub-humid temperate highlands in the Central Himalayas of Himachal Pradesh and did not observe much horizon differentiation and classified those as Mollic Udorthents and Fluventic Hapludolls. During 1994, they also studied four profiles in North-Western Himalayas and named those soils as Typic Udorthents, Typic Eutrochrepts and Typic Udifluvents.


According to Sidhu et al. (1997), the soils of Himachal Pradesh belonged to four Ordes, six Suborders, twelve Great groups, seventeen Subgroups and forty three families. The Entisols are dominant soils and cover about 51 per cent area, followed by Inceptisols, Mollisols and Alfisols which cover 20.0, 0.8 and 0.4 per cent of total geographical area of the state, respectively. The rock outcrops constitute about 28 percent of the total geographical area.
Singh et al. (1999) studied twelve representative pedons of poorly managed terraces of Kumaon hills and classified the soils of as *Typic Argidolls*, *Ultic Hapludalfs* and *Typic Eutrudefts*.

Sidhu et al. (1999) characterized and classified seven pedons representing different physiographic units of Jammu and Kashmir. Shallow, loamy and very severely eroded soils on hill tops of lesser Himalayas were classified as *Lithic Udorthents*. Very deep, fine-loamy, slightly acidic to neutral and moderately eroded soils on side slopes of Shivaliks were classified as *Dystric Ustochrepts*, deep coarse loamy, neutral and moderately eroded piedmont soils as *Udic Ustochrepts*.

Mahapatra et al. (2000) grouped the soils occurring in the subhumid ecosystem of Kashmir region as *Entisols, Inceptisols, Alfisols* and *Mollisols*.

Gupta et al. (2001) characterized the soils of Kandi belt of Jammu region and classified those as *Ustifluvents and Ustorthents*.

Baruah et al. (2002) classified the typical pedons of Loktak catchment area of Manipur representing major landforms *viz.* very steep high hill slope, steep high medium hill slope, moderately sloping foot hill slope and very gently sloping plain, developed from shale and occurring at different elevations and under varying land uses as *Humic Dystrudepts, Humic Hapludults, Typic Haplohumults, Typic Palehumults* and *Aquic Haplohumults*.

Sen et al. (2003) presented a detailed account on nature, classification, distribution, land use limitation, potential and management of major soils of Assam for agricultural planning and development.

Sharma et al. (2004) characterized the cultivated soils of Neogal watershed in North-West Himalayas occurring on river terraces and hill slopes. The soils on moderately sloping hill slopes were classified as *Typic Udorthents* and those on gently to moderately sloping river terraces as *Typic Dystrudepts* and *Typic Hapludalfs*.

On the basis of the reconnaissance soil survey of Solan tehsil, the soils belonged to *Typic Hapludalfs, Typic Argiudolls, Typic Udifluvents* and *Dystric Eutrudepts* (Chaudhary et al. 2005).

Kumar and Verma (2005) characterized seven pedons from rice-growing soils of Palam valley as moderately acidic to neutral in reaction, high to very low in organic carbon, mixed in mineralogy, deep to very deep, low to medium in available N, P and low to high in available K. The pedons were classified as *Typic Hapludalfs* and *Typic Dystrochrepts*.

Mahapatra et al. (2005) classified the soils of Kumaon Himalayas as *Typic Dystrudepts, Typic Udorthents* and *Typic Haplustepts*.

Tripathi et al. (2006) studied four typical pedons representing major landforms of Solan district of Himachal Pradesh. The soils were neutral to slightly alkaline, mixed in mineralogy, shallow to very deep and silty loam to loam. They observed the evidences of clay illuviation in sub-soils in majority of these soils and classified those as *Typic Udorthents, Dystric Eutrudepts* and *Typic Dystrdepts*.

Chaudhary and Singh (2007) studied four pedons from Solan district of Himachal Pradesh and classified the soils on very steep hill slopes as *Typic Udifluvents* and on strongly sloping terraces as *Dystric Eutrudepts* and *Typic Eutrudepts*. They observed that the illuviation of clay and bases were more conspicuous in soils developed at lower elevations with milder slopes compared to those occupying higher physiographic positions.

Sunita and Bandyopadhyay (2008) studied soils of Sikkim on nine broad landform units and classified those as *Inceptisols, Entisols* and *Mollisols*.

Sharma and Chaudhary (2008) reported the presence of three soil orders *viz. Entisols, Inceptisols* and *Alfisols* in Shivalik hills of Himachal Pradesh.

Sahoo et al. (2010) studied the eight representative soil profiles occurring on high hill, medium hill, low hill and foot hill slopes in Manipur and classified those as *Lithic Dystrudepts, Typic Dystrudepts, Typic Kandiudults, Typic Kanhapludalfs* and *Typic Hapludalfs*.

An appreciable attempt has been made by some workers and premier organizations for compiling the information on soil resource mapping at national
level from time to time (Murthy et al. 1982; Sohan Lal et al. 1994). Two soil series viz. Rajpura (Typic Paleudalfs) and Mataur (Dystric Eutrochrepts) have been established to represent the majority of soils of mid- and low- hills zone of Himachal Pradesh. Their efforts made it easy to understand important soil forming factors and processes in Indian conditions. The soil map of country on 1:7 million scale, state soil maps on 1:250,000 scale, district soil maps on 1:50,000 scale, soil degradation map of the country on 1:44 mm scale and agro-ecological map of the country (based on physiography, soil, climate, length of growing period and available soil moisture on 1:44 million scale) have also been prepared by National Bureau of Soil Survey and Land use planning for meeting out the database requirements for landuse planning at a macro-level.

Himachal Pradesh Krishi Vishavidyalaya has also done some soil survey work in Himachal Pradesh at 1:50,000 scale. The area comprised of catchments of Satluj (upper), Giri, Bata, Soan, Neogal and Nakehr rivers. Major great groups identified were: Cryothents, Dystrochrepts, Eutrochrepts, Hapludalfs, Hapludolls, Paleudalfs, Psammments, Udorthents, Ustochrepts and Ustorthents (Anonymous 1988; Verma, 1979; Sharma and Karan Singh, 1991; Sharma et al. 1993 and Sharma et al., 1998a and 1998b).

The review of literature on soil characterization and classification reveals that availability of soil and terrain databases is limited in Himachal Pradesh for watershed planning. Further, there has been more emphasis on fundamental as compared to the applied purposes of soil survey.

2.2 Soil fertility mapping

Soil fertility status is also an important parameter for land evaluation. Soil fertility is affected by the natural (climate, biosphere, parent material, topography and time) and artificial factors viz. management practices (fertilization, manuring, green-manuring, crop rotations etc.). The primary purpose of soil testing is to provide basis for location specific fertilizer recommendations for high yields. An effort has been made to review the fertility status of soils of Himachal Pradesh vis-a-vis of India.

Thakur et al. (1971) found that the cultivated soils of Seeraj and Karsog blocks in Mandi district of Himachal Pradesh were medium in available N and low in available P and K.
Ghosh and Hasan (1976) rated majority of Indian soils as medium, high and low in available K to the extent of 42, 38 and 20 per cent, respectively.

Verma et al. (1976) reported that the cultivated soils of Kangra region of Himachal Pradesh were low in available N, P and K. Ghosh and Hasan (1979) reported that available P status in Indian soils was medium, low and high to the extent of 52, 46 and 2 per cent, respectively.

Ghosh and Hasan (1980) prepared a map of nitrogen status of Indian soils and found that many soils of hill regions including Himachal Pradesh were high in available N, while those of plains were low to medium in N status. Takkar and Nayyar (1981) observed Fe and Mn deficiencies in cultivated alluvial plains of Punjab.

Verma and Tripathi (1982) reported that available nitrogen content in Una and Hamirpur districts varied from 113 to 228 kg ha\(^{-1}\) while it ranged from 295 to 503 kg ha\(^{-1}\) in Kangra, Mandi, Bilaspur, Shimla and Sirmour districts of Himachal Pradesh.

Verma et al. (1985) characterized the soils of Kangra, Kullu, Mandi and Sirmour areas of Himachal Pradesh and found the contents of both available P and K ranging from 2.69 to 28.22 kg ha\(^{-1}\) and 4.26 to 1507 kg ha\(^{-1}\), respectively.

Raina (1988) studied the citrus growing soils of Paonta valley in Himachal Pradesh and reported the soils as low in available N, medium to high in available P and medium in available K. Gupta and Tripathi (1989) observed that exchangeable calcium in the soils of North-West Himalayas were medium to high in status (2.2 to 10.5 cmol (p\(^{+}\)) kg\(^{-1}\)).

In a soil fertility map of Himachal Pradesh, the soils of Kangra district were rated as medium in available N, low in available P and medium in available K (Anonymous 1988).

Kaistha and Gupta (1993) reported that exchangeable Ca and Mg in sub-humid temperate highlands of Himachal Pradesh varied from 3.7 to 15.3 and 0.1 to 4.2 cmol (p\(^{+}\)) kg\(^{-1}\), respectively.

Gupta and Tripathi (1996) reported that exchangeable Mg contents in the soils of North-West Himalayas ranged from 0.7 to 10.5 cmol (p\(^{+}\)) kg\(^{-1}\).
According to Anonymous (2001), 51, 36 and 59 per cent of Indian soils were high, medium and low in available N; 6, 45 and 49 per cent in available P and 52, 39 and 9 per cent in available K. Further, 20 to 25 and 35 to 40 per cent of soil samples studied were deficient in available S and Zn, respectively.

Mahajan (2001) reported the soils of Mandi district in Himachal Pradesh as medium in available N (384 to 492 kg ha\(^{-1}\)), P (17 to 22 kg ha\(^{-1}\)) and K (231 to 235 kg ha\(^{-1}\)), high in exchangeable Ca (4.0 to 5.1 cmol (p\(^+\)) kg\(^{-1}\)) and Mg (1.7 to 2.4 cmol (p\(^+\)) kg\(^{-1}\)) and high in DTPA extractable Fe (91 to 129 ppm), Mn (1.3 to 3.5 ppm), Zn (5.5 to 8.3 ppm) and Cu (1.7 to 2.8 ppm).

Singh (2001) revealed that 12, 5, 49 and 3 per cent soils of India were deficient in available Fe, Mn, Zn and Cu, respectively. Out of 3,650,004 samples of Indian soils, per cent soil samples which fell in low, medium and high categories were 63, 26, and 11 in case of available N; 42, 38, 20 in case of available P; 13, 37 and 50 in case of available K and 40, 35 and 25 percent in case of available S, respectively (Motsara 2002).

Sharma et al. (2002) reported that soils of Fatehpur block in Himachal Pradesh were low to high in available N and P and low to medium in available K, sufficient in exchangeable Ca and Mg and deficient to sufficient in available micronutrient cations.

Sharma and Kumar (2003) reported that soils of agricultural lands of mid-hill soil zone were medium to high in available N, low to medium in available P and low to high in available K.

Tandon (2004) reported that about 63, 44, 21 and 37 per cent of Indian soils were low in available N, P, K and S, respectively.

CSK Himachal Pradesh Agricultural University, Palampur prepared a soil fertility map of Himachal Pradesh at a block level. Available N, P and K status were low to medium in majority of the blocks (Anonymous 2005).

Kumar and Verma (2005) studied the fertility status of rice growing soils of Palam valley of Himachal Pradesh and reported that the soils were low to medium in available N and P and low to high available K.

Shekhar (2009) observed that exchangeable magnesium content in surface soils of forest, grassland and cultivated lands of high rainfall areas in
Kangra, Chamba and Mandi districts of Himachal Pradesh fell in low category. Singh (2009) reported a deficiency of about 41, 12, 5 and 4 per cent of available S, Fe, Mn, Zn and Cu, respectively in soils of India and predicted that Zn deficiency is further expected to increase from 48 to 63 per cent by the year 2025 as most of the marginal soils are brought under cultivation.

The review of literature revealed that soil fertility mapping was done by using administrative boundaries as mapping units. Further, soil fertility characterization is focused mainly on cultivated lands. Non-agricultural lands under forests and scrublands/grasslands are usually placed under neglected side. There is limited information on soil fertility mapping using soil taxon as a mapping unit.

Soil fertility maps of India prepared by Ramamurthy and Bajaj (1969) and Ghosh and Hasan (1976) suffers from limitations like lack of representative character of samples especially because of non-recognizance of pedological classification of soils and little control on the choice of sampling sites. Accordingly, use of this information either to develop meaningful recommendations or to monitor soil fertility changes becomes questionable.

Sekhon et al. (1985) suggested soil series as a basis for soil fertility mapping. Soil fertility mapping and fertilizer recommendations made on soil series basis are more scientific than those on the basis of administrative units e.g. district, block etc. Earlier, Linsley and Bauer (1929) prepared soil fertility maps on soil series basis. Parker et al. (1951) advocated the use of Nutrient Index concept for comparing the levels of soil fertility between the soil series. Chamuah et al. (1989) observed a considerable variation in paddy responses to applied N, P and K in different soil series. Similar results were also reported for wheat (Naidu et al. 1988).

2.3 Land capability classification

The USDA land capability classification serves as a guide to assess suitability of the land for arable crops, grazing, forestry, etc. Though majority of lands are not being used as per their capabilities, land capability classification in those areas helps in providing warning signals/ precautionary measures to sustain existing land use.
Tejwani and Dhruvanarayana (1961) proposed a soil conservation plan based on different capability classes. Class I lands needed no conservation measures. In Class-II lands, contour bunding and measures like contour cropping and strip cropping were suggested. Class III and IV lands needed peripheral bunding and safe outlets for the discharge of excess run-off, clearing and minor leveling on gully sides and beds, putting up of check-dams, brick masonry across the gully beds, good crop rotations, heavy application of manures and fertilizers for improving soil fertility, etc.

Murthy et al. (1968) recommended the construction of bench terraces with protected disposal drains for reducing the run-off velocity and checking the degree of erosion in sloping lands and used land capability classification system for sound watershed planning.

Walia et al. (1987) conducted the soil survey of Bilaspur district of Himachal Pradesh and interpreted soil survey data for land capability, land irrigability classification for optimum land use planning.

Rajinder Kumar et al. (1995) advocated for the adoption of suitable conservation measures based on land capability. This approach led to runoff decline from 65 to 30-34 per cent and the soil loss dwindling from 22.5 t ha$^{-1}$ to about 3-4.3 t ha$^{-1}$ in a 26 ha agricultural watershed in HPKV, Palampur farm.

Karim et al. (1999) used land capability classification criterion for growing organic arabic coffee on hill slopes.

Sheng (2000) introduced a ‘Treatment Oriented’ land capability classification scheme for the development of hilly watersheds in the humid tropics. Expert systems have been developed to facilitate that work.

Patel et al. (2001) undertook a study in a Solani watershed of Uttarakhand and Uttar Pradesh for assessing the land capability to adopt suitable soil conservation measures and appropriate land uses through remote sensing and GIS approaches. They got good short- and long- term results.

Rodriques et al. (2001) used land capability classification approach and Geographic Information System for watershed planning in Brazil.

Sarkar et al. (2002) placed the high hill soils such as *Humic Dystrudepts* and *Humic Hapludults* in the land capability sub-class Vles due to the very
steep slope, very severe erosion, low moisture holding capacity and high soil acidity while the foot hill soils (*Typic Palehumults*) into capability sub-classes Illes and IIsw.

Sharma et al. (2004) classified the soils of Neogal watershed area in North-West Himalayas into land capability sub-classes IIle and III.

Shekinah et al. (2004) grouped the soils of Sahaspur block of Uttarakhand under six land capability classes viz. class II (good cultivable lands), class III (moderately good cultivable lands), class IV (fairly good cultivable lands), class VI (non-arable lands), class VII (fairly suited to grazing and forestry) and class VII (non-arable lands).

Martin and Saha (2009) delineated four major land capability classes viz. Ile, Illes, IVes and Ves in Dehradun district, Uttarakhand. Soil erosion was found to be the major limitation followed by wetness, soil depth, texture and slope.

Sahoo et al. (2010) reported that high hills, medium hills, low hills and foot hills in Manipur belong to Illes, IVe, IVes, Vle, VIIes and VIIIe land capability subclasses.

The land capability sub-classes in Lendi watershed of Maharashtra indicated that the watershed has moderately good to fairly good cultivable land with limitations of texture, soil depth, slope, wetness and erosion problems. The non-arable land is moderately to well-suited for grazing or forestry due to wetness and soil erosion hazards (Patil et al. 2010).

It may be concluded that land capability classification have been used by many workers as a guide to sustain land uses.

### 2.4 Soil productivity evaluation

It is difficult rather impossible to evaluate the suitability of a soil for different uses agronomically. Field experiments require much more time, money and labour. Riquier et al.’s (1970) and Storie (1978) proposed indirect and quantitative models for soil productivity evaluation. These models are widely accepted and used for optimum land use planning. Former model has an advantage of computing actual soil productivity, potential soil productivity and
the coefficient of improvement. Actual soil productivity is the initial capability of a soil to produce a certain amount of crops per hectare per annum following the existing farm practices, while soil potentiality is the productivity of a soil when all possible land improvements including the most difficult and costly ones have been made.

Kumar et al. (1984) prepared the actual soil productivity and potential soil productivity maps on the basis of Riquier et al.’s system.

Using Riquier et al.’s model, Kumar and Saxena (1985) assessed some benchmark soils of Punjab for actual and potential productivity and found that productivity of Lithic Ustorthents and Lithic Udorthents was poor. Though Natrualstals were found to be ‘Extremely poor’ at present, their productivity can be improved by 8 to 10 times by following reclamation measures. Salorthids and Natrargids, suffering from shrinking and swelling problems, had poor to actual as well as potential productivity.

Naidu et al. (1986) assessed the productivity and potentiality of eight extensively occurring soil series of Delhi. They found that Kakra and Rajpur series had poor productivity class. Soil texture and moisture were found to be the predominant factors affecting soil productivity indices.

Sohan Lal (1989) evaluated sixty four benchmark soils using modified Storie Soil Rating System and reported that the soils occurring on steep slopes belonged to grade 5 and 6. Arid and poorly drained soils fell under grade 3 and 4. He observed a significant correlation between Storie Index and wheat yield with farmer’s and improved practices.

Sharma et al. (1989) studied the present productivity capacity of the soils of Doon valley, supporting sal (Shorea robusta) forest and rated as average soil productivity indices.

Walia and Chamuah (1992) reported higher productivity potentials in soils of Assam under teak plantation than those under grazing and shifting cultivation.

Sharma et al. (1993) rated the Soan river valley soils of lower Shivaliks in Himachal Pradesh as poor to very poor in productivity.
Naphade et al. (1994) assessed the productivity potential of a *Typic Chrostert* in Akola for sorghum, wheat, cotton and groundnut by using Requier’s productivity indices and rated these soils as ‘good’ for growing crops.

Gaikawad et al. (1995) evaluated eleven series of Gadchiroli district of Maharashtra for their productivity potentials based on soil-site characteristics and reported extremely high productivity potentials (*Typic Haplusterts*) to extremely low productivity potentials (*Lithic Ustorthents*).

Kumar (1996) evaluated the soils of HPKV farm in district Kangra of Himachal Pradesh for their productivity potentials. All the soils were fair to good in productivity except *Dystrochrepts* which were poor in land productivity.

Mayalagu et al. (1998) surveyed Tamil Nadu Agricultural University farm for the determination of land capability classes and soil productivity potentials. Two soil series namely, *Palathurai* (*Typic Haplustalf*) and *Perianaickanpalayan* (*Typic chromustert*) were found to be most productive.

Mandal et al. (2002) rated the cotton-growing soils of Nagpur district of Maharashtra as per Riquier’s criteria and observed a significant correlation between crop yield at farmer’s fields and productivity indices. Similarly, Tamgadge et al. (2002) studied fourteen different soils under paddy cultivation in Chhattisgarh state and found a positive correlation.

Sharma and Anil Kumar (2003) used Riquiers’ approach for sustainable land use planning for agricultural and non-agricultural lands.

Sharma (2003) conducted a detailed soil survey of Chimbal-har micro-watershed in mid hills subhumid zone of Himachal Pradesh and reported that soils were ‘Good’ to ‘Excellent’ in actual soil productivity and ‘Excellent’ in potential productivity for crop growing crops. A similar study was also conducted in Neogal watershed in North-West Himalayas (Sharma et al. 2004). Gebrekidan et al. (2005) evaluated the productivity potential on three distinct toposequences in Hima catchment and observed ‘Extremely poor’ to ‘Poor’ potentials in mountainous areas and good in valley areas.

Bhatta et al. (2005) studied the soils of Budhabudhiani irrigation project in Nayagarh district of Orissa and classified into ‘Good’ and ‘Excellent’ actual and potential productivity classes, respectively.
Bharat Bhushan et al. (2005) evaluated the soils of micro watersheds in north eastern tract of India for productivity potential of soils using standard procedure given by Storie (1978) and Riquier (1970). According to Storie, the soils were rated as poor to very poor but according to Riquier, the soils were ‘Poor’ to ‘Nil’.

Gabhane et al. (2006) compared the production potential of benchmark soils of Akola district in Maharashtra using various qualitative and quantitative approaches.

Chaudhary and Singh (2007) assessed the productivity potential of different physiographic positions in Solan district of Himachal Pradesh as per Riquier et al.’s indices. *Typic Udifuvents* and *Typic Eutrudepts* were found to be as ‘Average’ and ‘Good’ in actual and potential soil productivity, respectively.

Using Storie Rating Index, 5, 8 and 16 per cent of the total geographical area of Shivalik hills in Himachal Pradesh was rated as ‘Fair’, ‘Poor’ and ‘Very poor’ in soil productivity, respectively (Sharma and Chaudhary 2008).