Principles of soil classification: Genetic School and USDA
Principles of land classification: UK and USDA

Part II (1+1+1 System) Geography Hons.
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Principle of Soil Classification (Genetic)

Purpose of soil classification: Like the flora and fauna, soils are classified in some systematic manner so as to remember their properties and understand relationships. The purpose of any classification is to

I. organize knowledge leading to economy of thought
II. recognise and remember properties of the object(s) classified
III. bring out, understand and learn new relationships and principles in the population being classified
IV. establish groups or subdivisions (classes) of the objects under study in a manner useful for practical and applied purposes in
    - predicting their behaviour
    - identifying their potential uses
    - estimating their productivity
    - providing objects for research and
    - transferring agro-technology from research farms to cultivators' fields.

Dokuchaiev's Genetic System

In the later part of the 19th century, Dokuchaiev, a Russian scientist, while working in central Russian Upland, realised a rather uniform loess-like parent material that extends for hundreds of kilometres where an increasing temperature gradient is imposed from North to South and an increasing rainfall and moisture gradient from East to West. These differences in climatic elements were associated with important vegetation patterns, varying from forest to steppe (prairie), and left their imprint on the parent material producing distinct soil differences. These observations led Dokuchaiev - the founder of modern pedology - to establish the concept of soil as an independent natural body and resulted in a series of publications on soil genesis and classification (Docuchaiev, 1886). Therefore, the Russian approach to soil classification is naturally tended to emphasize on soil genesis and hence the term Genetic System of soil classification.

Dokuchaiev (1900) divided soils into three categories; Normal, Transitional and Abnormal (Table 1). These categories were later termed as Zonal, Intrazonal and Azonal soils, respectively.

Table 1: Dokuchaiev's (1900) soil classification scheme

	Zones	**Soil type**
Class A:	**Normal Soils (Zonal)**	
	Boreal	Tundra (dark brown) Soils
	Taiga	Light-grey Podzolized Soils
	Forest Steppe	Grey and Dark-grey Soils
	Steppe	Chernozem
	Desert Steppe	Chestnut and Brown Soils
	Aerial or Desert zone	Aerial Soil (brought down by wind), Yellow Soils, White Soils etc.
	Subtropical and tropical forests	Laterite or Red Soils
Class B:	**Transitional Soils (Intrazonal)**	Dryland Moor Soils or Moor Meadow Soils
		Carbonate-containing Soils
		Secondary Alkaline Soils
Class C:	**Abnormal Soils (Azonal)**	Moor Soils
		Alluvial Soils
		Aeolian Soils (brought down by wind)

Zonality Concept: The soils that have fully developed soil profiles, and are in equilibrium with the environmental conditions, such as climate and vegetation, are termed as Zonal Soils, for instance Sierozem, Chestnut, Podzols and Laterites. The soils, where time has been a limiting factor to produce horizonation are termed as Azonal Soils. Most of the recent (Late Holocene) alluvial deposits or dunes or severely-eroded areas support Azonal Soils, for instance, Alluvial Soils and Regosols. Still other soils occurring within the zonal areas and having characteristics that are determined by the local conditions, such as topography, specific parent material, are termed as Intrazonal Soils, for instance, Calcimorphic and Hydromorphic Soils.

Although the Russian approach was based on sound principles of soil genesis, yet the approach had some inherent weakness of having laid undue emphasis on climate and vegetation rather than on the intrinsic properties of soils. However, the principles of the Russian approach are still in vogue and used in different soil classification systems, but at different categorical levels.

Marbut's (Morpho-Genetic) System

Marhut was the central figure in the evolution of soil taxonomy in the USA. He was greatly influenced by the Dokuchaiev's approach. He accepted the concept of the Russian Soil Type, but gave it the name of Great Soil Groups. Marbut (1927) was the first to advocate classification of soils on the basis of their intrinsic properties rather than on soil- forming factors, thus reducing emphasis on geology or parent rock.Jarbut evolved his scheme in successive steps and published in the Atlas of American Agriculture (Table 9.2). It was based on the iron-alumina and lime contents. At the highest categorical level, he divided Zonal Soils into two classes: Pedalfers and Pedocals. The former showing accumulation of iron and aluminium and the latter of calcium as calcium carbonate. The Pedalfers were presumed to occur in areas of high rainfall having real surplus water for leaching. The Pectocals occur in areas of low rainfall and high evaporative demand, with real deficit of water.

Marbut emphasized that soil classification should be based on soil morphology and stressed the need for examination of actual soils for their characteristics, such as colour, texture, structure, consistency, thickness and arrangement of horizons, drainage condition, nature of parent-material, occurrence of lime, soluble salts or organic matter.

The major limitation of this system was that it was based, in part, on the assumptions concerning soil genesis.

Baldwin and Associates' Genetic Approach

In view of the limitations, the Morpho-genetic System of Marbut was revised and elaborated by Baldwin, et al. (1938) and Kellogg and Thorp (1949) (Table 9.3). The System marked the beginning of a comprehensive approach. The salient features of the System are:

- A return of the zonality concept of the Russian School.
- The pedocal-pedalfer concept was deemphasised.

According to the revised system (Table 2), the soils were grouped in three Orders, viz., Zonal, Intrazonal and Azonal, following the Russians zonality concept, as under:

Zonal Soils: The soils whose characteristics are determined primarily by the environment, especially climate and vegetation. The differences due to the parent material are considered subordinate to the dominating influence of climate. The soils are termed as Zonal because the development of their profiles corresponds to the climatic and vegetation zones in which they occur (Fig. 9.1).

Intrazonal Soils: The soils occurring within a zone but reflect the influence of some local conditions, such as topography and/or parent material. Under these conditions, the characteristics imparted by the local condition(s) predominate.

Azonal Soils: The soils that have poorly-developed profiles because of time as a limiting factor. For instance, young soils are generally without horizon differentiation. The soils developed on recently-laid parent materials (alluvium, colluvium or aeolian) belong to this group.

The three Orders are further subdivided into 9 Suborders on the basis of specific climatic and vegetative regions. Each of the Suborder, in turn, is divided into Great Soil Groups which are an expression of more specific conditions. The Great Soil Groups are further subdivided into numerous Soil Families, Series and Soil Types.

Table 2: Morpho-genetic System of soil classification
(Baldwin *et* al. 1938, as modified by Throp and Smith, 1949)

Order	Suborder	Great Soil groups
Zonal Soils	1. Soils of the cold zone	▪ Tundra Soils
	2. Light-coloured Soils of arid region	▪ Sierozem Soils
		▪ Brown Soils
		▪ Reddish Brown Soils
		▪ Desert Soils
		▪ Red Desert Soils
	3. Dark-coloured Soils of the semi-arid, sub-humid and humid grasslands	▪ Chestnut Soils
		▪ Reddish Chestnut Soils
		▪ Chernozem Soils
		▪ Prairie or Brunizem Soils
		▪ Reddish Prairie Soils
	4. Soils of the forest grassland transition	▪ Degraded Chernozem Soils
		▪ Noncalcic Brown Soils
	5. Light-coloured Podzolized Soils of the timbered regions	▪ Podzol Soils
		▪ Gray Wooded or Gray Podzolic Soils
		▪ Brown Podzoloc Soils
		▪ Soil-brun acide
		▪ Gray-brown Podzolic Soils
		▪ Red-yellow Podzolic Soils
	6. Lateritic Soils of forested warm-temperate and tropical regions	▪ Reddish-brown Lateritic Soils
		▪ Yellowish-brown Lateritic Soils
		▪ Lateritic Soils
Intrazonal Soils	1. Halomorphic (saline and alkali) Soils of imperfectly drained, arid regions and littoral deposits	▪ Solonchak or Saline Soils
		▪ Solonetz Soils (partly leached Solonchak)
		▪ Soloth Soils
	2. Hydromorphic Soils of marshes, swamps, seep areas and flats	▪ Humic-gley Soils
		▪ Alpine Meadow Soils
		▪ Bog and half-bog Soils
		▪ Low humic Gley Soils
		▪ Planosols
		▪ Groundwater Podzol Soils
		▪ Groundwater Laterite Soils
	3. Calcimorphic Soils	▪ Brown Forest Soils
		▪ Rendzina Soils
Azonal Soils	No Suborder	▪ Lithosols
		▪ Alluvial Soils
		▪ Regosols

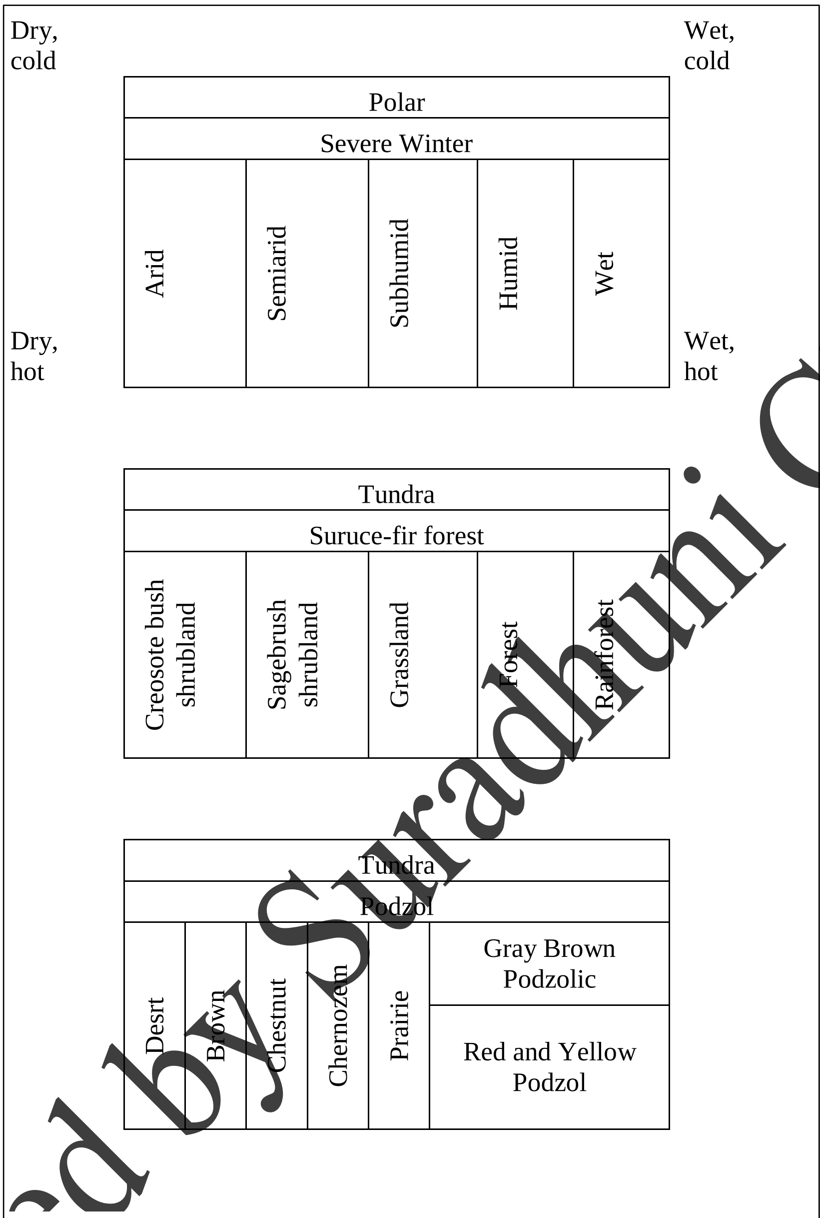

Fig: A schematic relationship of climate, vegetation and soils (top, climate types; middle, vegetation types; bottom, soil groups)

Limitations in the Genetic System of Soil Classification

• The Great Soil Group concepts and definitions are based on environmental factors, rather than the soil properties. Hence their definitions are comparative and qualitative. As such, it is difficult to obtain agreement amongst different workers.

• Many of the soils are defined in terms of properties that were obvious under virgin soil conditions and are destroyed during cultivation, and hence the classification of such arable soils becomes ambiguous.

Soil classification: USDA

Soil classification developed by United States Department of Agriculture and the National Cooperative Soil Survey provides an elaborate classification of soil types.

Soil taxonomic classifications reflect the dominant soil forming factors active during soil formation at a particular location. The USDA system of soil taxonomy (soil naming) consists of a hierarchy of six levels. These levels, in order from most general to most specific, are:

- Order
- Suborder
- Great Group
- Subgroup
- Family
- Series

- **Order** – Twelve soil orders are recognized. The differences among orders reflect the dominant soil forming processes and the degree of soil formation. Each order is identified by a word ending in 'sol.' An example is Alfisols.
- **Suborder** - Each order is divided into suborders primarily on the basis of properties that influence soil formation and/or are important to plant growth.
- **Great Group** – Each suborder is divided into great groups on the basis of similarities in horizons present, soil moisture or temperature regimes, or other significant soil properties.
- **Subgroup** – Each great group has a typical subgroup which is basically defined by the Great Group. Other Subgroups are transitions to other orders, suborders, or great groups due to properties that distinguish it from the great group.
- **Family** – Families are established within a subgroup on the basis of physical and chemical properties along with other characteristics that affect management.
- **Series** – The series consists of soils within a family that have horizons similar in color, texture, structure, reaction, consistence, mineral and chemical composition, and arrangement in the profile.

Soil Order	Key Characteristics
1. Entisols	• Soils with little profile development • Many different parent materials contribute to varied soil properties of this order. • Often found in very dry or cool locations • Geographically extensive, commonly found with aridisols. • Widely varied productivity potential • Extent of world ice-free land area: 16%
2. Inceptisols	• The beginnings of soil profile development • Color differences between horizons starting to show • Prominent in mountainous areas, but occur almost everywhere • Widely variable productivity potential • Extent of world ice-free land area: 10%
3. Aridisols	• Soils of arid, desert climates • Varied parent materials • Often have accumulations of lime ($CaCO_3$), sodium or salts. • Can be made productive if irrigation water is available. • Found extensively in tropical latitudes, rain shadows and arid climates. • Extent of world ice-free land area: 12%
4. Mollisols	• Mineral soils developed under grassland vegetation • Thick, dark-colored 'A' horizon, rich in organic matter • Dominant soil order of the North American Great Plains region.

	• Large areas of Mollisols are also found in Eastern Europe, Russia, China, and South America. • Generally very fertile for plant growth due to clay and organic matter content. • Considered to be among the most fertile soils on Earth. • Extent of world ice-free land area: 7%
5. Alfisols	• Found under forest and savanna vegetation • Clay accumulations in subsoil horizons • Often are leached below topsoil (E horizon) • Generally fertile, with high base saturation%. • Comparable in productivity to Mollisols and Ultisols. • Extensive in humid mid-latitudes • Extent of world ice-free land area: 10%
6. Spodosols	• Form in sandy materials under coniferous forest vegetation • Usually associated with a wet, cool climate • Coarse texture, high leaching potential • Have a Spodic horizon, composed of organic matter, Fe and Al oxides • Acidic, with low natural fertility • Require inputs of lime and fertilizers to be agriculturally productive. • Commonly formed in northern Europe, Russia, and northeastern North America • Extent of world ice-free land area: 4%
7. Ultisols	• Intensely weathered soils of humid areas • Form on older geologic locations in weathered parent materials • Contain subsurface clay accumulations (claypans). • Low in natural fertility (Ca^{2+}, Mg^{2+}, and K^{+}) and high in soil acidity (H^{+}, Al^{3+}) • Can be agriculturally productive with inputs of lime and fertilizers • Occur extensively in the southeastern USA, China , Indonesia, South America, and equatorial regions of Africa • Extent of world ice-free land area: 8%
8. Oxisols	• The most highly-weathered soils • Form in hot, humid climates with high annual rainfall. • Commonlyoccur in equatorial latitudes. • Highly weathered and leached, dominated by iron and aluminum oxides. • Low in natural fertility (basic cations, Ca^{2+}, Mg^{2+}, K^{+}) and high in soil acidity (H^{+}, Al^{3+}) • Physically stable soils, with low shrink-swell properties. • Extent of world ice-free land area: 8%
9. Andisols	• Form in regions of recent volcanism • Volcanic parent materials • Generally high in natural fertility • 'Light' soils that are easily cultivated. • Potentially very productive soils • Limited geographic distribution • Extent of world ice-free land area: 1%
10. Gelisols	• Soils with frozen subsoils (permafrost) • Limited profile development • Surface accumulations of soil organic matter • Productivity limited by short growing season • Extensive in high latitudes • Extent of world ice-free land area: 9%

11.	Histosols	• Organic Peat Lands, or Boggy soils • Consist of layered organic materials (more than 20% organic materials by mass) • Form in cool, wetland environments • Do not contain permafrost. • Found mainly in geographically high latitude areas or other marshy wetlands. • Extent of world ice-free land area: 1%
12.	Vertisols	• Soils with high content of shrinking/swelling clay minerals. • Self-mixing due to shrink-swell of clay minerals • Dark colored with variable organic matter content (1 – 6%) • Typically form in limestone or basalt, or in topographic depressions. • Most commonly formed in warm, subhumid or semi-arid climates. • Large areas are found in Northeastern Africa, India, and Australia, with smaller areas scattered worldwide. • Extent of world ice-free land area: 2%

Concept of Land Capability

Land capability classification is a scientific appraisal of the physical characters of the land, inherent soil qualities and management practices. The main objective of land capability classification is to understand potentiality, capability and suitability for the optimum utilisation of land. Land capability measurement offers a scientific judgment for the conservation of land under specific ecological conditions.

Land capability in one hand helps to find out efficiency of land for particular uses and on the other it helps to prevent improper use of land which leads to erosion hazards and deterioration of land quality. So, for the sake of optimum productivity, the capability of each and every bit of land should be measured considering its inherent pedo-geomorphic characters as well as limitations due to environmental hazards. Besides, capability classification enables the farmers to use the land properly for sustainable production under required management measures.

Land Classification in UK (after L.D. Stamp)

Prof. L. D. Stamp (1938) prepared a scheme of land classification suitable for a broad national policy of land use planning and land resource conservation. He classified lands into three major categories and ten subsequent types on the basis of site, elevation, slope, nature of relief, depth of soil, water conditions, texture etc.

Stamp's Scheme of Land Classification

Major Category	Land Types	Characteristic Features
I-Good - quality land		Not too elevated, level, gently sloping or undulating, favourable aspect, deep soil, actual or potential water conditions, mostly loamy texture including some peats, sands, silts and clays.
	1.First class land	Capable of intensive cultivation particularly for food stuffs; soils are deep, mainly loamy texture including some peats, fine sands, silts and loamy clays. Drainage should be free but not excessive and soils should not be excessively stony. It must be workable at all seasons.
	2. Good general purpose farm-land	This type is similar to the first category but it varies with some respect i.e. (a) less depth of soil, or (b) presence of stones, or (c) occasionally liable to drought or wetness, or (d) some limitation of seasons when soil works easily, resulting in a restriction of the range of usefulness. The land is suitable for arable cultivation under the aforesaid conditions.
	3.First class land with water conditions especially favouring grass	This land is similar/analogous to that of land type 1, but it varies with respect to (a) a high permanent water-table, or (b) liability to winter or occasional flooding, or (c) somewhat heavier or less tractable soils, which is unsuitable or less suitable for arable cultivation than grass.
	4. Good but heavy land	The land reflects soils of good depth. Natural fertility is often high. Soils are heavy, mostly, better clays and heavy loams with the result that both the period of working and the range of possible crops are restricted. Boulder clays of Scotland represent this type of land.
II-Medium quality land		Characterised by high elevation, steepness, unfavourable aspect, shallowness, defective water conditions etc. The land is of medium productivity when under good management.
	5. Medium-quality light land	It is defective of lightness and shallowness of soil. The moderate elevation, relatively gentle slopes and other aspects are satisfactory. The distinct types include (a) shallow, light soils on chalk or Jurassic limestones, (b) shallow soils of older limestones and shallow light soils occur on other rocks, (c) light soils, but not shallow, including gravels.
	6. Medium-	The land is defective because of (a) land broken up by steep slopes, with patches of

	quality general purpose farmland	considerable elevation, varied aspect and varied water conditions, (b) soils are varied often deficient by reason of stoniness, shallowness, heaviness or in other ways. This land category favours a mixture of crops and grass.
III-Poor quality land		It is characterized by low productivity due to extreme heaviness and/or wetness of soil, extreme elevation and/or ruggedness and/or shallowness of soil, extreme lightness of soil etc. The land is agriculturally useless.
	7. Poor-quality heavy land	This is characterised by extreme heaviness and/or wetness of soil. It includes more intractable clay lands and low-lying areas of un-drained masses which needs extensive drainage works before they can be rendered agriculturally useful.
	8. Poor quality mountain and moorland	Reflects extreme elevation and/or ruggedness and/or shallowness of soil. It is apparently covered by the varied character of natural or semi-natural vegetation.
	9. Poor-quality light land	Characterized by extreme lightness of soil with attendant drought and poverty. This category includes over-drained lands, usually overlying coarse sands or porous gravels including both coastal sand dunes and inland sandy 'wastes' or heath lands.
	10. Poorest land	This land may be agriculturally useless due to the several above mentioned factors in combination. But there are possibilities of reclaiming such lands. Salt marshes can be drained and sand dunes can be fixed.

Land Classification by USDA Method

The Soil Conservation Service of the U.S. Department of Agriculture classified lands into eight capability classes mostly on the basis of topographic situation.

The land capability classification consists of three categories, namely:
(i) Capability Classes
(ii) Capability Subclasses and
(iii) Capability Units

1. Capability Classes
In all eight Capability Classes are recognized. The soils having greatest capability for response to management and least limitations are grouped in Class-I and those having least capability and greatest limitations are grouped in Class-VIII.
(A) Class I-IV includes land suited for cultivation.
(B) Class V-VIII land not suited for cultivation.

(A) Land suited for cultivation
Class I.: Soils in Class I have no or only slight, permanent limitation or risks of damage. They are very good. They can be cultivated safely with ordinary good farming methods. The soils are deep, productive, easily worked and nearly level. They are not subject to overflow (run-off) damage. However, they are subject to fertility and puddle erosion. Soils of this class have no or only slight risks of damage.
Management: Class I soils used for crops, need practices to maintain soil fertility and soil structure. These practices involve use of fertilizers and lime, cover and green manure crop, crop residues and crop rotations.

Class II: Class II consists of soils, subject to moderate limitations in use. They are subject to moderate risk of damage. They are good soils. They can be cultivated with easily applied practices. Soils in Class II differ from soils in Class I in a number of ways. They differ mainly because they have gentle slopes, are subject to moderate erosion, are of moderate depth, are subject to occasional overflows and are in need of drainage. Each of these factors requires special attention.
Management: These soils may require special practices such as soil conserving rotations, water control devices or special tillage methods. They frequently need a combination of practices.

Class III: Soils in Class III are subject to severe limitations in use for cropland. They are subject to severe risks or damage. They are moderately good soils. They can be used regularly for crops, provided they are planted to good rotations and given the proper treatment. Soils in this class have moderately steep slopes, are subject to more severe erosion and are inherently low in fertility.

Management: These soils require cropping systems that produce adequate plant cover. The cover is needed to protect the soil from erosion. It also helps preserve soil structure. Hay or other sod crops should be grown instead of cultivated row crops. A combination of practices is needed to farm the land safely.

Class IV. Soils of this group have very severe permanent limitations or hazards if used for crop land. The soils are fairly good. They may be cultivated occasionally if handled with great care. For the most part, they should be kept in permanent hay or sod. Soils in Class IV have unfavorable characteristics. They are frequently on steep slops and subject to severe erosion. They are restricted in their suitability for crop use. The soils are shallow or moderately deep, low in fertility and on moderate slopes.
Management: These soils should be in a hay or sod crops for long periods. Only occasionally should they be planted to row crops.

(B) Soils not suited for cultivation
Class V. Soils in Class V should be kept in permanent vegetation. They should he used for pasture or forestry. Cultivation is not feasible, however, because of wetness, stoniness or other limitations. The land is nearly level. It is subject to only slight erosion by wind or water if properly managed. They have few or no permanent limitations and not more than slight hazards.
Management: Grazing should be regulated. So that plant cover is maintained.

Class VI. Soils of this class should be used for grazing and forestry. They have moderate permanent limitations and are unsuitable for cultivation. They are steep or shallow. Class VI land is either steeper or more subject to wind erosion than Class IV. Class VI land is too steep or subject to wind erosion.
Management: Grazing should not be permitted to destroy the plant cover. Call VI land is capable of producing forage or wood land products when properly managed. .

Class VII. Soils in Class VII are subject to severe permanent limitations (or hazards) when used for grazing of forestry. They are steep, eroded, rough, shallow, droughty or swampy. They are fair to poor for grazing or forestry.
Management: Where rainfall is ample, land should be used for woodland. In other areas, it should be used for grazing. In the latter case, strict management should be applied.

Class VIII. Soils of this class are extremely rough even for woodland or grazing. They are not suited for forestry or grazing. They should be used for wildlife, recreation or watershed.

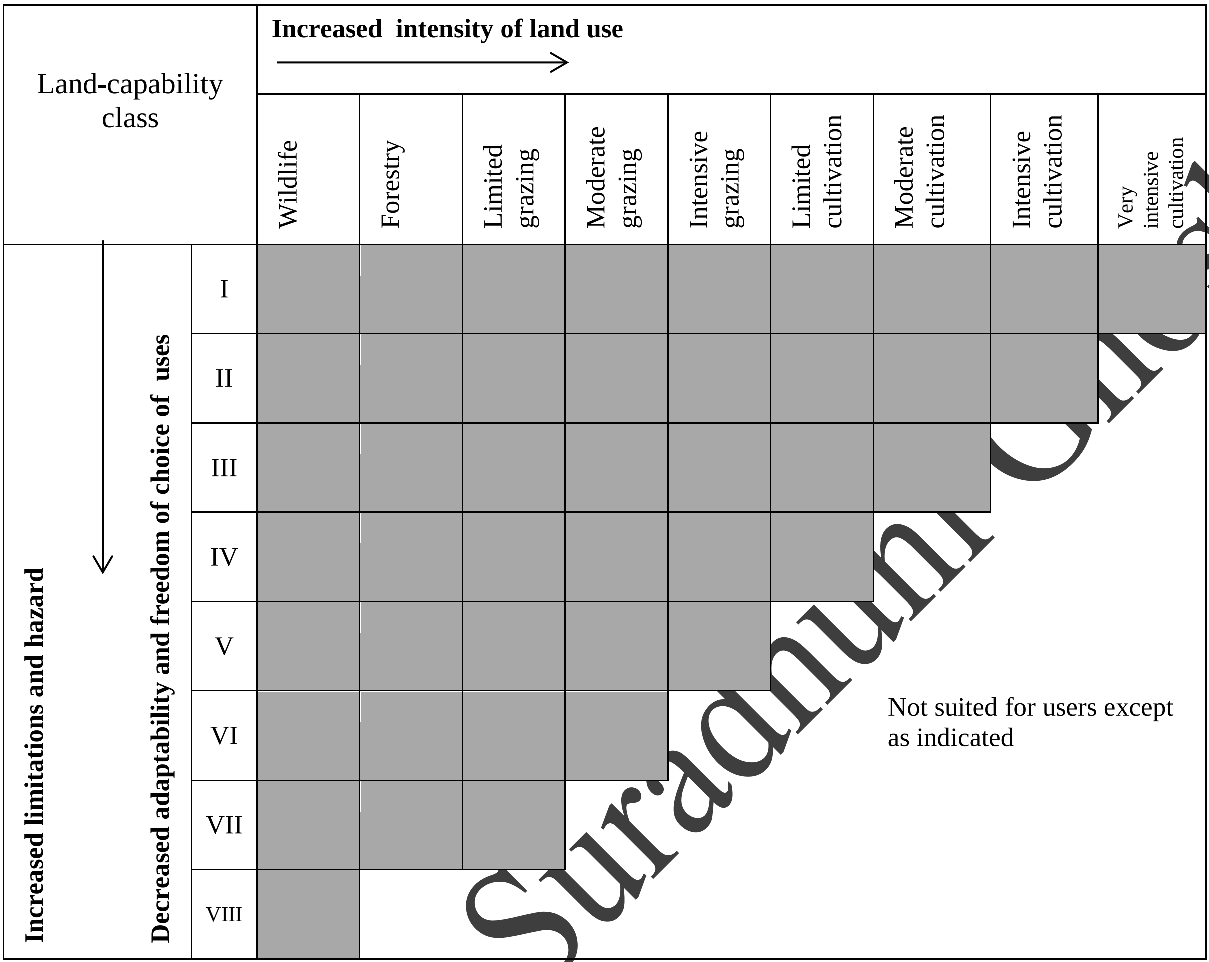

Fig: Land Use Capability Classification

Capability Subclasses

The Capability Subclasses are based on kinds of dominant limitation, such as

- ‘e’ denotes erosion hazard (when vulnerability of soil is the main problem in its use)
- ‘w’ denotes wetness (when excess water is the main problem)
- ‘c’ denotes climate (when climate, e.g. temperature or lack of moisture is the main problem)
- ‘s’ denotes soil(when limitations of the soil e.g. salinity are main problem)

The Subclasses are mapped by adding limitation symbols to the Capability Class number subscripts, for example IIe, IIIw, etc. Therefore, the Subclasses indicate both the degree and kind of limitations. The Capability Subclasses provide information as to the kind of conservation problems or limitations involved. There are no Subclasses in Capability Class-I land, since there is no limitation in this class.

Capability Units

These are further subdivisions of Capability Subclasses. A Capability Unit includes soils which are sufficiently uniform in their characteristics, potential and limitations and require fairly-uniform conservation treatment and management practices.