Review Article

Comment [U1]: This manuscript is very well-written; it only needs the addition of a map showing the research location.

Soil diversity of Himachal Pradesh: Addressing key issues and crafting solutions

Abstract

The soils of Himachal Pradesh face a multitude of pressing issues that threaten their health and agricultural productivity.The diverse geographical features, temperature regimes and biological zones of Himachal Pradesh have resulted into a vast range of soil types in the state. Alpine, forest, alluvial and sub-mountain soils are the four majorsoil categories into which the state's soils can be generally divided. Only a particular species and adapted plants can thrive in the extreme weather circumstances of alpine soils, which are located at higher elevations and possess soils havingthin, stony and acidic in reaction. The mid-hill areas are dominated by forest soils which are distinguished by their high levels of organic matter and nutrients. These soils support luxuriant vegetation and make effective agricultural methods possible. Alluvial soils, which are mostly found in river valleys and are deposited by ravine systems are extremely rich and perfect in fertility and suitable for growing a range of crops including vegetables, rice and maize. Located in the foothills, sub-mountain soil exhibits a blend of traits from alluvial and forest soils, thus providing a range of uses for horticulture and agriculture. In addition to supporting a diverse array of plant and animal life, Himachal Pradesh's varied soil types are vital to the region's agricultural economy. One of the biggest problems is soil erosion, which is made worse by the steep terrain and abundant rainfall in the area. This results in the loss of topsoil and decreased fertility. Deforestation, overgrazing, and unsustainable farming methods all contribute to land degradation, which further reduces biodiversity and soil quality. Furthermore, crop development is impacted by soil acidity in high-altitude regions, which restricts nutrient availability.However, these issues needefficient conservation measures and soil management techniques.In order to maintain Himachal Pradesh's rich biodiversity and agricultural potential for future generations, sustainable agricultural development and environmental protection in this ecologically sensitive area depend on an understanding of the complex soil dynamics.Addressing these interconnected issues requires a comprehensive approach, emphasizing sustainable land management practices, community engagement, and restoration efforts to preserve the vital soil resources of this ecologically sensitive region.

Keywords: Himachal Pradesh, soils, management, agriculture, taxonomy

Introduction

Himachal Pradesh is situated in lower Himalayan region with numerous mountain ranges and rich natural resources. It is embellished with mountains situated at 30°22'40" East latitude and 33°12’20" North latitudes and 75°45'55" and 79°04'20" East . The altitude ranges varies from 320 m to 6,000 m. There is a preponderance of tiny holdings in the state, more than 85 per cent of the holdings are small and marginal owning less than two hectares of land and accounting for about 51 per cent of the operated area. The overall average size of holdings is 1.10 hectares (Anonymous, 2016). HP is divided into four agro-climatic zones based on the altitude and other climatological parameters. The average rainfall is around 1800 mm. Physio-graphically, the area is divided into 4 main regions *viz.*, Greater Himalayas, Lesser Himalayas, Shivaliks and Alluvial Plains. Taxonomically, Himachal Pradesh is classified into 14 types of soil, the soils of Greater Himalayas is divided into 5 types, the soils of Lesser Himalayas is of 3 types, the soils of Shivaliks is of 4 types and the Soils of

Alluvial Plains is of 2 in count. There are 4 major soil orders i.e. Entisols (51.5 %), Inceptisols(19.7%), Mollisols (0.8 %), Alfisols (0.4%) and Rock outcrops covers the 27.7 per cent area of total geographic area of Himachal Pradesh (Sidhu *et al.,* 2007). There are nine major groups of soils *viz.,* Alluvial soils, Brown hill soils, Non-Calcic Brown soils, Brown Forest soils, Grey Wooded Soils, Grey Brown Podzolic soils, Planosolic Soils, Humus and Iron Podzols, Alpine Humus Mountain Skeletal Soils (Verma and Tripathi, 1982; Verma *et al.,* 1985 and Singh *et al.,*1996). The information of soil erosion, depth and pH is useful for diagnosis of problem and potential of soil. Out of the total geographical area, 53.8 per cent area is affected by water erosion, 23.1 per cent area is affected by stoniness and 18 percent of total geographic area is suffered from shallowness in this state (Sidhu *et al.,* 2007). Agronomic and engineering practices like contour farming, contour strip-cropping, terraces, diversions, Contour buffer strips, field borders, filter strips, riparian forest buffers, organic matter application, liming and construction of Poly houses showed good results by reducing the extent of these problems and hence are being adopted by the farmers and scientists of the state.

The state of Himachal Pradesh, which is located in the North-Western Himalayas, has a variety of agricultural systems and climates. The state makes up 1.69per cent of the total land area of the nation with its 55,673 sq km of territory. Situated in the lower Himalayan region, Himachal Pradesh boasts an abundance of natural resources and multiple mountain ranges. 37,033 square kilometers, or 4.8 per cent of India's total land area, are covered by forests. Approximately 17 per cent of this area is made up of glaciers (2,554 in total), 17.7 per cent is made up of barren and uncultivated land, 33.4 per cent is made up of permanent pastures and other grazing lands, and 12 per cent is net sown land (Himachal Pradesh Department of Revenue, 2017). The range of altitudes is between 320 and 6,000 meters. About 1800 mm of rain falls there on average. The state is divided into 12 districts: Mandi, Shimla, Sirmaur, Solan, Una, Kinnaur, Kullu, Hamirpur, Kangra, Lahul and Spiti and Chamba. According to geography, the state is bordered by China in the east, Uttarakhand in the south-east, Haryana in the south, and Punjab in the west and north (Anonymous, 2020).

The Himalayan region's mid-hills zone, which spans from 651 to 1800 meters above mean sea level and has a mildly moderate climate, makes about 32 per cent of the state's total land area and roughly 37 per cent of its agricultural area (Parmar, 2014). Himachal Pradesh is well-known for producing off-season vegetables all year round. Because of the favourable climate, farmers in mountainous locations can grow a wide range of income crops and vegetables during the off-season. However, if they cultivate the land without following optimal management methods, the soil becomes less fertile, which degrades the environment.

The need for alternative uses is causing the limited area beneath the fertile soils in mountain landscapes to become even more significant. This is because there is less land available for agriculture. In these circumstances, the farmers' high cropping intensity and dishonest use of chemical fertilizers in an attempt to increase production have finally resulted in the region's soils having a depleted nutritional status (Sharma *et al*., 2001). When deciding when and how much fertilizer to apply, a farmer must consider the needs of the crops as well as the properties of the soil. Farm-based livelihoods are at risk due to the indiscriminate or unbalanced use of chemical fertilizers caused by a lack of knowledge about soil health. To ensure higher agricultural yields and prudent fertilizer use, the fertility level of the soil must be ascertained. The most precise method for determining the availability of different plant nutrients is the soil test, which is one of the diagnostic tools used to evaluate fertility along with fertilizer trails and plant analysis. In order to comprehend the existing soil fertility state of the mid-Himalayan region, the current study was planned. This would help the farmers to

make more informed decisions to increase the productivity of their lands and to improve their livelihood.

Physiography of Himachal Pradesh

The state of Himachal Pradesh, which is essentially a hilly environment, has notable features that include steep mountain ranges sliced by sharply divided valleys carved out on slopes of varied kinds. The Leo Pargil Peak in Kinnaur District is 6975 meters above mean sea level, while the elevation in Una District is 320 meters. The State can be split into five separate parallel zones physio-graphically (Geological Survey of India, 2012).

a) Alluvial Plains

This zone is defined by virtually level plains that are situated at an average elevation of 375 meters at the base of the Shivalik Range. This zone includes the Una district. In the district, two types of soils are found: non-calcic brown soils and alluvial soils. Because of their high nutritional content, soils are fruitful.

b) Siwalik Foothills

The westernmost hilly region of the Himachal Himalayas, often referred to as Sub-Himalaya, divides the state from the plains of Punjab and Haryana. This zone tapers to a smaller width in Nalagarh and Kiarda Duns (Paonta) in the east, and it is roughly 50 km broad in the west, 80 km wide in the Kangra valley. The zone is 8 km to 50 km wide and has an altitude range of 345 m to 1500 m. This region is home to numerous notable longitudinal valleys, such as the Una and Kangra valleys. Due to the region's hills' extremely unconsolidated deposit base, erosion and deforestation occur at a rapid pace.

c) Lesser Himalayan Zone

Between the Sub-Himalaya and the Central Himalaya is a zone that is 65–80 km wide. This zone rarely rises beyond 3000 meters. Gradual rise towards the Dhauladhar and PirPangal ranges is indicative of this zone. Near the Sutlej river, the PirPangal, the largest of the smaller Himalayan ranges, splits off from the Greater Himalayan range.

d) Central Himalayan/Great Himalayan Zone

The Chandrabhaga basin's northern watershed is formed by the Great Himalayan range, which also divides it from the Spiti basin. To the east, the range creates the watershed between the Spiti and Beas basins. It consists of a range of peaks, between 5000 and 6000 meters high, covered in snow. It divides the Trans-Himalayan zone with the Lesser Himalayan zone. Several well-known passes include Pin Parvati (4,802 m), Bara Lacha (4,512 m), and Kangla (5,248 m).

e) Trans Himalayan/Higher Himalayan Zone

The Eurasian plate colliding with the Himalaya created the Trans Himalaya. This zone, which includes the states of Jammu and Kashmir and Himachal Pradesh, is the northernmost part of the nation. The region is primarily covered by rain shadow, with an average width of 40 km and heights ranging from 3000 to 6000 meters. The three main ranges are East Korakoram, Ladakh, and Dhauladhar.

Geology of Himachal Pradesh

The state features four physio-geographic regions *viz.* the Greater HimalayanZone, Lesser Himalayan Zone, Outer Himalayan Zone and Tethys Himalayan Zone. Elevation generally increases from West to East and from South to North. There are several lesser ranges, including Zanskar, Dhauladhar and PirPanjal, contained inside these enormous mountains. Four broad, simplified strati-graphical zones can be used to classify the region's complex geology; these zones are derived from the classifications of Ganser(1964), Singh &Bhandari (2000) and Srikantia and Bhargava (1998).

a) Outer or Sub-Himalayan zone

The foothill zone, often referred to as the Shiwaliks, is primarily made up of tertiary formations, which include thick detrital rocks, clays, and conglomerates. The rocks of the sub-Himalayan zone include the Subathu, Dagshiai and Kasauli deposits, as well as the Shiwalik Group. The rocks are arranged from oldest to youngest. The Subathu deposits constitute the shallow marine rocks at the foot of the series. Shiwalik rocks are mostly composed of limestones, mudstones, red, fine-grained sandstones, siltstones, a thin series of shales capped by a hard, white-gray sandstone rich in quartz, and softer green-colored sandstone, among other types of rock.

b) Lower Himalayan zone

The Central Himalayan thrust and the Main border thrust are separated by the Lower Himalayan zone. The primary sedimentary deposits in this zone are early Proterozoic detrital sediments that were deposited between 1900 and 1800 million years ago. These sediments were then overthrusted onto sub-Himalayan rocks along the Main Boundary Thrust (MBT) as a result of Himalayan upliftment. Massive quartz with intruding basalts and other crystalline rocks of non-fossiliferous sediments make up the majority of the Lesser Himalaya. The almost complete Paleozoic sediments in the Lower Himalaya is suddenly interrupted by the transgression of the outstandingly different Gondwana rock sequence. The "Panjalvolcanics" or "Panjal Traps" are the formations that are the result of this well-preserved volcanic activity in the PirPanjal range. The Lesser Himalayan Crystalline Sequence appears within the Larji-Kullu-Rampur window, a tectonic window along the Sutlej sector. Granitic gneiss and thick mica schist make up this unit's lowest portion.

c) Higher Himalayan zone

This zone is the primary metamorphic unit that forms the crystalline core zone throughout the whole Himalaya. The zone at its base is covered by the Main Central Thrust (MCT), a large fault that allowed for up to 250 km of shortening during collision.

d) Tethys Himalayan zone

The Tethyan Himalaya is a fairly continuous sedimentary series that was deposited in the Spiti region during the Upper Proterozoic and the Eocene. Generally speaking, only extremely low-grade metamorphism occurred in these sediments. A defining feature of this area is the rusty ferrous slates and KinnaurKailash Granite, which forcefully thrust the Lesser Himalaya over the sub-Himalaya. As the Indian peninsula continues to push against the Eurasian Plate, the Himalayas and the related eastern ranges are still tectonically active.

Agro-climatic zones of Himachal Pradesh

Based on altitude and other climatic factors, HP is split into four agro-climatic zones. Wet-Temperate, High-Hills (where,peas, french beans, cauliflower and cabbage are grown), Dry-Temperate, High-Hills, Cold Deserts (where quality seed of temperate and off-season vegetables is produced), b) Sub-Temperate, Sub-Humid, Mid-Hills (where cash crops like ginger are grown), c) Wet-Tropical, Sub Mountain, Low-Hills (where all vegetables are grown), In Himachal Pradesh, the net area seeded is 5.38 lakhs/ha, while the gross cropped area is around 9.51 lakhs/ha out of the entire geographical area. The cropping intensity is 16.6per cent.

Land use classification of Himachal Pradesh

According to the surveyor General of India, the total geographical area in the State is 5567 thousand hectares.Because of its varied topography and climate, the northern Indian

state of Himachal Pradesh has a wide land use classification. This is a general summary of the area's land use:

a) **Forest Land:**Holds up a bigger portion of the state's total land area, forests cover a sizable chunk of Himachal Pradesh. Coniferous, deciduous and alpine plants make up these forests which are abundant in biodiversity (table. 1).
b) **Recreational places and tourists:** Because of its picturesque scenery, some places are set aside for tourists, which affect land use patterns, especially in well-known locations.
c) **Agricultural Land:** Approximately 10-15% of the land is used for farming, making agriculture a significant activity. Rice, maize, wheat, barley and a variety of fruits particularly apples and cherries are the state's main crops.
d) **Waste Land:** Wasteland is defined as areas unsuitable for forest cover or agriculture. This involves rocky regions, precipitous hills, and erosion-prone locations.
e) **Water Bodies:** The land use classification also includes rivers, lakes, and reservoirs, which are essential for hydropower and irrigation.
f) **Pasture Land:** In higher elevations where traditional pastoral methods are practiced, pastureland is crucial for livestock grazing.
g) **Urban Areas:** Although they make up a smaller portion of the state's land usage, the towns and cities of Shimla, Manali and Dharamshala are vital for government and tourism.

Table 1. Land use classification of Himachal Pradesh

Sr. No.	Land use classification	Area (%)
1.	Forests	24.2
2.	Barren and unculturable land	17.7
3.	Land put to non-agricultural uses	7.0
4.	Culturable wastelands	2.7
5.	Permanent Pastures and other Grazing Lands	33.4
6.	Land under Miscellaneous Tree Crops not included in net area sown	1.3
7.	Other Fallow Lands	0.3
8.	Current Fallow	1.3
9.	Net Area Sown	12.0

(Source: Geological Survey of India, 2012)

Land Capability Classes and their limitation and potential in Himachal Pradesh

According to Sidhu and Yadav, 2016 soils particularly those in mid and high-hill regions, are severely degraded and are not being used to their full potential. Therefore, to prevent future degradation of the land, proper land use planning is a need. This calls for the creation of maps showing the area's soil and land capability as well as a thorough soil study of each micro watershed (table. 2).

Table 2. Land capability classes and production potential under Himachal Pradesh state

Land capability classes	Area (per cent)	Limitation	Production potential

LCC- III	6.7	Moderate problems due to moderate depth, gravels, moderate slopes subject to water erosion.	Moderately good cultivable land.
LCC- IV	14.7	Moderately steep lands subject to serious water erosion, shallow depth, gravels and stones.	Fairly good land suited for cultivation
LCC- VI	23.1	Steep lands subject to severe erosion if cover is depleted.	Well suited for grazing, forestry and limited cultivation
LCC- VII	14.8	Very steep lands subject to erosion, if cover is depleted, very shallow and stony soils.	Fairly well suited for grazing or forestry, not arable
LCC- VIII	40.7	Highly erodible gullies, badlands, barren mountain tops and rock outcrops.	Suited only for wildlife, recreation and permanent snow covered as protection of water supplies.

(Source: Sidhu et al., 2007)

Soils diversity of Himachal Pradesh

Himachal Pradesh has a diverse range of soils due to its varied topography, climate and vegetation (table. 3 and 4). The important characteristics along with taxonomic classification of dominant soils (Sidhu *et al.,* 2007) are as follows. Because to its unique topography, temperature and vegetation, Himachal Pradesh has a wide variety of soil types. An outline of the key traits and taxonomic groupings of the predominant soils in the area is provided below:

1. Features of Alfisols

a) Usually fertile, with a horizon rich in clay.
b) Moisture retention is good since it is well drained.
c) They are appropriate for agriculture due to their moderate to high nutritional content.
d) Located in the mid-hills as it provides support for pulses, wheat and maize.

2. Features of Inceptisols

a) Young soils with a moderate level of development.
b) Variable fertility and good drainage.
c) Frequently found in regions with parent materials or recent alluvial deposits.
d) Location: Usually found in river valleys and more recent agricultural areas.

3. Features of Entisols

a) Very young soils with little horizon formation.
b) Often less fertile, frequently sandy or loamy.
c) Prone to erosion and particularly found in the steep terrains.
d) Location: Usually found along riverbanks and on steep slopes.

4. Features of ofUltisols

a) Acidic soils with a subsurface rich in clay.
b) Lower nutrient levels as compared to alfisols, agricultural treatments might be necessary.
c) Location: Found in several valley regions and the lower slopes.

5. Features of Mollisols

a) High fertility, dark and organic-rich soils.
b) Outstanding nutritional levels and moisture retention.
c) Location: Usually utilized for intensive agriculture, but less frequent in some valley regions.

6. Features of Podzols

a) Usually having a leached horizon, these soils are acidic and well-drained.
b) Low in organic matter and minerals.
c) Location: Usually found beneath coniferous trees in cooler, higher-altitude regions.

Table 3. Important soil characteristics of soils of Himachal Pradesh

Physiographic Unit	Soil Characteristics	Soil Taxonomy	Area (%)
Soils of greater Himalaya			
Summits and ridge tops	Shallow to medium deep, excessively drained, sandy-skeletal to loamy-skeletal, high calcareous with low organic content and AWC**,** slightly alkaline and severely eroded.	*Lithic Cryorthents* and *TypicCryorthents*	4.6
Mountain and valley glaciers	It also have same characteristics like Summits and ridge tops but these are covered with snow for longer time.	*Lithic Cryorthents* and *TypicCryorthents*	3.6
Slide/ Reposed slopes	Shallow to medium deep, well to excessively drained, loamy-skeletal and coarse-loamy, both calcareous and non calcareous, slightly acidic to slightly alkaline, severely eroded soils with low organic content and AWC and moderate to strong stoniness.	*Lithic/ TypicUdorthents*, *TypicEutrocryepts* and *DystricEutrocrye pts*	36.1
Glacio-Fluvial valley	Medium deep to deep, well to excessively drained, loamy soils having low AWC. They are dominantly slight acidic to neutral with medium to high contents of calcareous and slightly to moderately alkaline.	*Lithic/TypicCryor thents*, *TypicEutrocryept s* and *DystricEutrudepts*	2.3
Fluvial valley	Medium deep to deep, well to somewhat excessively drained, loamy-skeletal, slightly acidic to neutral soils with low AWC.	*TypicUdorthents/ Udifluvents* and *Dystric/ TypicEutrudepts*	0.5
Soils of Lesser Himalayas			
Summits and ridge tops	Shallow to medium deep, well to excessively drained, coarse-loamy and fine loamy, neutral to slightly alkaline soil with low to medium AWC and severe erosion	*TypicUdorthents* and *DystricEutrudepts*	0.7

Slide/Reposed slopes	Shallow to medium deep And deep, well to excessively drained, sandy, loamy-skeletal, coarse-loamy and fine loamy calcareous as well as non calcareous soils. They are slightly acidic to neutral on high hills and neutral to slightly alkaline on lower hills. The organic matter content is very high.	*Lithic/TypicUdorthents*, *Typic/DystricEutrudepts* and *TypicHapludolls*	28.9
Fluvial valley	Medium deep to deep, well to excessively drained, stratified coarse-loamy and fine-loamy, mostly non-calcareous and neutral to slightly alkaline soils with moderate to high organic content status and medium AWC	*TypicUdifluvents/ Udorthents*and *DystricEutrudepts*	1.9
Soils of Shivaliks			
Summits and ridge tops	Medium deep to deep, well excessively drained, loamy skeletal soils with severe to very severe erosion. They are slightly acidic to slightly alkaline with moderate to high organic content status and low AWC.	*Lithic/TypicUdorthents*	0.4
Slide/ Reposed slopes	Medium deep to deep, well to excessively drained, loamy-skeletal, coarse-loamy and fine-loamy soils with moderate to severe erosion. They are slightly acidic to slightly alkaline with low to moderate organic content and AWC status.	*Lithic/TypicUdorthents*, *Typic/DystricEutrudepts* and *TypicHapludolls*	17.6
Fluvial valley	Medium deep to deep, well drained, sandy, sandy-skeletal, coarse-loamy and fine loamy and soils with moderate erosion. They are neutral to slightly and moderate alkaline with low to medium organic matter content and AWC.	*TypicUstorthents*, *TypicUstifluvents*. *TypicHaplustepts* and *TypicHapludalfs*	1.5
Piedmont Plains	Medium deep to deep, well drained, coarse-loamy soils with severe erosion. They are calcareous as well as non-calcareous and slightly to moderately alkaline with low to medium organic content status and medium AWC.	*TypicUstorthents* and *UdicHaplustepts*	1.2
Soils of Alluvial Plains			
Alluvial piedmont plains	Medium deep to deep, well drained, coarse and fine-loamy soils with slight to moderate erosion. They are calcareous as well as non calcareous, neutral to slightly and moderately alkaline with medium organic content status and medium to high AWC.	*TypicEutrudepts*, *DystricEutrudepts* and *TypicUdifluvents*	0.3

Active flood plains	Deep, well to excessively drained, mostly stratified coarse-loamy and fine-loamy soils with slight erosion and stoniness, prone to slight and moderate flooding.	*TypicUstifluvents* and *TypicUstipsamments*	0.3

(Source: Sidhu et al., 2007)

Middleton classification of soils

a) **Chaih:** Irrigated by wells.
b) **Nehri :** Land irrigated by gravity Canals which are perennial in character.
c) **Nehri I:** Land receiving water from the non-perennial source or only at times.
d) **Nad:** Inundated land, growing only rice crop.
e) **Dofasli (Unirrigated):**Bearing two crops a year or three in two years.
f) **Ek-Fasli (Unirrigated):** This type of land produces only one crop in a year.
g) **BahndBanjar:** It bears one crop in two to three years. Per acre yield is generally poor.
h) **Kharetar:** These are hay-fields and pastures.

The soils found in Himachal Pradesh can be broadly categorized into two groups: transported or drift soils found in valleys, depressions, and along gentler hill slopes, and residual or sedimentary soils found on high hill summits, spurs, or plateaus. The soils of the state can be roughly classified into nine classes according to their physico-chemical qualities and development (Yadava and Thakur, 1972; Verma 1979; Verma and Tripathi, 1982; Verma*et al.,* 1985; Singh *et al.,* 1996; Ray Chowdhury and GovindaRajan, 1971).

Soils classification of Himachal Pradesh on the basis of physico-chemical properties

1. Alluvial soils
2. Brown Hill soils
3. Non-Calcic Brown soils
4. Brown Forest Soils
5. Grey Wooded or Brown Podzolic Soils
6. Grey Brown Podzolic soils
7. Planosolic Soils
8. Humus and Iron Podzols
9. Alpine Humus Mountain Skeletal Soils

1. Alluvial soils

Alluvial soils are characterized by the incipient profile development and are found in the districts of Una (Una district), Indora (Kangra district), and Poanta (Sirmaur district), where the floodplain is the predominant physiography. They are distinguished by their early profile development. Based on USDA Soil Taxonomy, these soils belong to *Udifluvents* and *Eutrochrepts* (Soil Survey Staff, 1990). These are often coarse-textured soils with a pH of greater than 6.5, low levels of organic matter, and a mixture of loamy sand, sandy loam, and, on rare occasions, loam to sandy clay loam. The calcareous composition of the soils ranges from 2.0 to 4.5 percent calcium carbonate.

2. Brown hill soils

Brown hill soils can be found in Nahan (Sirmour district) and Solan (Solan district), with a texture ranging from sandy loam to clay loam. Due to their medium to high levels of organic matter, these soils have a neutral to slightly acidic pH. The soils

are categorized as *Udorthents, Hapludols*, and *Hapludalfs* in accordance with the soil taxonomy.

3. **Non-Calcic Brown soils**

Not Calcic Aside from the areas of Dehra Gopipur (Kangra district), brown soils are typically found in sections of the districts of Hamirpur, Bilaspur, and Mandi. Most of the time, soil reactions are neutral and sporadically acidic. The texture ranges from clay loam to loamy sand. The range of organic matter content is low to medium. The USDA Soil Taxonomy classifies these soils as *Hapludalfs* and *Eutrochrepts.*

4. **Brown Forest soils**

Dark brown Where there is forest vegetation in Chamba districts, there are areas with forest soils. Their solum is from relatively deep to deep. The textures range from sandy loam to clay loam, and their reactions range from slightly acidic to neutral. The soils fall into the *Hapludalf, Hapludolls*, and *Eutrochrepts* groups, depending on which comes first.

5. **Grey Wooded or Brown Podzolic Soils**

Brown Podzolic or Grey Wooded Parts of the districts of Kullu and Shimla, as well as the Karsog region of Mandi district, have soils that have frequently grown under varied degrees of podzolization. Their darker colors and higher levels of organic content are their defining characteristics. The soil reactivity varies from mildly to very acidic, with sandy loam to clay loam textures. The soils are members of the groups *Hapludalfs* and *Hapludolls.*

6. **Grey Brown Podzolic soils**

Brown Grey Parts of the Kangra district and the Mandi district's Joginder Nagar area have podzolic soils, which are created by the predominant process of podzolization. The thick texture of clay loam, silt loam, and silty clay soils makes them clearly acidic in reactivity. These soils are categorized as *Paleudalf, Hapludalf*, and *Haplorthods*in soil taxonomy.

7. **Planosolic Soils**

These poorly drained soils are located in the Saproon valley of Solandistrict, the Nagwain area of Kullu district, theGhumarwin of Bilaspur district and the Balh valley of Mandi district. The texture of soils ranges from medium to fine, that is, from sandy loam to clay loam and neutral in reactivity. While accessible potassium and phosphorus are classified as being in the medium range, organic matter is typically in the medium to high range. According to soil classification, these soils belong to the *Ochraqualfs, Hapludalfs*, and *Haplaquepts* groups.

8. **Humus and Iron Podzols**

Iron with Humus Podzolization is the process by which podzols are created. They are mostly limited to areas in the regions of Dalhousie, Manali, and Shimla. These soils feature a dark A horizon that is reddish brown to yellowish brown in color, rich in organic matter and reacts acidically. Organic materials and free iron and aluminum are present in the B2 horizon. Different spodic horizons beneath Mollic or Umbricepipedons identify profiles.

9. **Alpine Humus Mountain Skeletal Soils**

These soils are located in the cold, low-precipitation Himalayan highlands that make up the districts of Kinnaur, Lahaul-Spiti, and Pangi tehsil of the Chamba district. The majority of soils are loamy, gravelly sand to loam, neutral in reactivity,

and rich in organic matter. Potassium and phosphorus availability are typically modest to high. These soils can be categorized as *Udorthents, Eutrochrepts*or*Hapludolls* according to soil classification.

Some other important soils characteristics of Himachal Pradesh

1. **On soil depth basis:**

Class	Depth (cm)	Area (%)
Shallow	50	18.0
Medium	50-100	35.2
Deep	>100	17.9

(Source: Sidhu et al., 2007)

2. **On soil particle class basis**

Class	Area (%)
Fragmental	1.1
Sandy-skeletal	9.3
Loamy-skeletal	23.9
Coarse-loamy	17.6
Fine-loamy	20.4

(Source: Sidhu et al., 2007)

3. **On water retention capacity basis**

Class	Available water (mm/m)	Area (%)
Very low	2	67.7
Medium	100-150	32.3

(Source: NBSS& LUP, Nagpur)

4. **On soil reaction classes**

Classes	pH	Area (%)
Moderately acidic	4.5-5.5	5.6
Slightly acidic	5.5-6.5	27.4
Neutral	6.5-7.5	21.7
Slightly alkaline	7.5-8.5	45.0

(Source: NBSS&LUP, Nagpur)

5. **On soil drainage classes**

Class	Area (%)
Excessive	49.6
Somewhat excessive	5.4
Moderately well	3.32

(Source: NBSS & LUP, Nagpur)

Soiltype	Color&texture	Otherfeatures	Sustainability interventions	Cropssuitable	Location
Low hillsoils (up to 650 maltitude)	Grayishtoyellowishbrown andLoamysand to sandy loam,embedded with Pebbles	Soils areneutralandLow to medium in SOC,CEC &WHC	Integratednutrientmanagementapproach	Wheat,Maize,Paddy, Gram, Mustard,Potato,Sugarcane,etc.	UnaandHamirpuranд parts ofBilaspur, Kangra,Mandi,Sirmaur, Solan andChamba
Mid hill soils(altitude from651to1800 m)	Dark YellowishbrowntodarkbrownandLoam to clayloam.	Soils areslightly tomoderately acidicandmediumtohighin SOC,CEC &WHC		Wheat, Maize, Barley, Black Gram,Beans, Paddy, Ginger, etc, andsuitable for quality seed production oftemperate vegetables like cauliflowerand rootcrops. Plantationcrop:Tea	Parts ofSirmaur,Solan, Bilaspur,Kangra, MandiandChamba
High hill soils(altitude from1801 to2200 m)	Light to dark brown,sandy loam to siltloam with varyingpercentageofgravels	Soils are slightly tomoderately acidicandmediumin SOC,CEC &WHC	Soil and water Conservationtechnology/Watershedmanagementtechnology	Wheat,maize,Barley,Pseudo-cereals, Potato etc. and suitable for qualityseedproduction of potato andtemperatevegetables.	Shimla,Kulluandsome parts ofSolan, Chamba,Mandi, Sirmaurand Kangradistricts
Mountainoussoils (altitude more than2200 m)	Loamy sand to sandyloam with varyingpercentageofgravelsand Lighttodark yellowishbrown	Soils are neutral to slightlyalkalineandlowtomedium in SOC,CEC &WHC		Wheat, Barley, Pseudo-cereals (Buckwheat and Amaranthus)and suitablefor quality seed production	Lahaul-Spiti ,KinnaurandPangidistrictofChamba

				oftemperateandEuropeanvegetables	

**CEC= Cation exchange capacity, WHC= Water holding capacity, SOC= Soil organic carbon (Source: HPStateBiodiversityBoard)*

Table 4. Diversity and crop suitability of soils in Himachal Pradesh

Soil conservation measures

In the State of Himachal Pradesh, soils are adversely affected by soil-erosion. The removal of organic matter and plant nutrients from the top layer and its leaching by the agents of denudation is called soil erosion. Unchecked erosion gradually leads to poverty of soil and undermines the strength of the land. Although there are a number of physical and socio-cultural factors responsible for the depletion and erosion of soil. The aspect of slope, precipitation, weather, temperature, wind, snowfall human action (overgrazing, defective crop-rotation) all combine to accentuate the rate of soil erosion. In order to overcome the problem of soil depletion and soil erosion, some of the important devices which need to be adopted are as under. The soil erosion can be checked by:

a) The maintenance of an effective vegetation cover
b) Contour ploughing
c) Rotation of crops
d) Terracing
e) Composting
f) Planting of cover crops
g) Creation of windbreaks (trees, fences)
h) Pipe-drainage to prevent gullying
i) Damning of gullies or filling them with brushwood

Problems and Management strategies

1. **Erosion**

   Soil erosion is one of the main causes of the depletion of natural resources. The process by which soil particles are separated and carried by the impact of raindrops is known as soil erosion. The process of finer particles being separated from aggregates by the kinetic energy of a raindrop is called detachment. In hilly regions compared to undulating ones, soil erosion is more severe (Sehgal, 2015).

Agents of soil erosion

a) Water
b) Biotic Factors
c) Wind

Since soil erosion is the primary form of soil deterioration, the state's soil resource map has been used to calculate the amount of water-induced soil erosion in Himachal Pradesh. According to the data, around 22per cent of the state HP's total geographic area has annual soil loss of less than 5 t/ha, which is considered to be well within the tolerance limit.Throughout the state, these regions are dispersed in little patches. A little over 7per cent and 5per cent of regions, respectively, experience yearly soil loss in the range of 5-10 and 10-15.0 t/ha. While there are pockets of these locations throughout the state, the districts of Hamirpur and Bilaspur do not include any areas with exceptionally severe erosion classes.The state experiences a total soil displacement of 258 Metric tonnes (Sidhu and Yadav, 2016).

Soil erosion classes of Himachal Pradesh

Class	Area (%)

Slight	2.0
Moderate	15.8
Severe	33.6
Very severe	2.3

(Source: Sidhu and Yadav, 2016)

Management of Soil Erosion

Controlling erosion with cropping and management practices

Inter-rill and rill erosion are the two forms of water erosion that are within the control of soil management techniques. It is typically necessary to use engineering features like reinforced stream-banks and grassed streams to reduce other forms of water erosion. The protection provided to the soil surface by the vegetative canopy, surface cover, and surface roughness are some of the cropping and management techniques used to control erosion (Duiker, 2014). In general, the following crop management techniques are crucial for reducing erosion:

1. Maintaining crop residue cover above 30per cent until crop canopy closure.
2. Alternating summer crops with winter crops and perennial crops.
3. Using cover crops during periods when the soil would have insufficient residue.
4. Contour farmingimplies that crops are planted nearly on the contour. The benefit of this practice is greatest on moderate slopes (2 to 6%) when crops are planted in tilled soil where ridge height is 2-3 inches. However, even with no-till, contour farming can reduce erosion if residue cover is marginal and ridge height is 2 inches or more.
5. Contour strip-cropping alternates perennial crops with strips of low residue cover or high residue cover. In rolling terrain, it is not always feasible to arrange the strips in close proximity to the contour. Typically, a strip's width falls between 75 and 120 feet. Because runoff velocity is slowed, soil that erodes from bare or low residue strips deposits in high residue or densely vegetated sections. The best results from this method come from tilling the soil or leaving it bare for a portion of the year when no-till farming is used. This approach is less effective since, in today's cropping systems, the variation in cover between strips is often very small.

Mitigating erosion by changing slope length and steepness

Runoff and soil loss increase with slope length and steepness. As is typical in South East Asia, flat terrace building can alter the steepness of a slope. Nonetheless, changing the steepness of a slope through management measures is not very prevalent in the United States. Installing terraces and runoff-diversion ditches can alter the slope's length. Although they are not immediately relevant to maintaining soil productivity on working farmland, additional erosion control techniques aid in maintaining the quality of the water. Although the following techniques do not directly improve soil quality, they are very useful in reducing the amount of silt and nutrients in surface waters:

1. Terraces are cross-slope channels that control erosion on cropland and are built so that crops can be grown on the terrace.
2. Diversions are similar to terraces, except that they are permanently vegetated with grass. They are used on steeper slopes where a terrace would be too expensive or difficult to build, maintain, or farm. They can also be used to protect barnyards from runoff.
3. **Contour buffer strips:**Permanently vegetated strips located between larger crop strips on sloping land.

4. **Field borders:**Bands or strips of permanent vegetation at the edge of a field.
5. **Filter strips:**Strips or areas of permanent vegetation used to reduce sediment, organic materials, nutrients, pesticides, and other contaminants from runoff.
6. **Riparian forest buffers:** Areas of trees and/or shrubs along streams, lakes, ponds, or wetlands.
7. **Vegetative barriers:** Narrow permanent strips of stiff-stemmed, tall, dense perennial vegetation established in parallel rows perpendicular to the dominant field slope.
8. **Grassed waterways:**Natural or constructed swales where water usually concentrates as it runs off a field.
9. **Streambank protection:** Structures such as fences and stable crossings to keep livestock out of the streams as well as stream-bank stabilization with rocks, grass, trees, shrubs, riprap, or gabions.
10. **Stoniness:**The term stony is applied to soils "having angular rock fragments over 3 inch in diameter". The chert fragments over 10 inch in diameter. In Himachal Pradesh 23.1 per cent area is affected with stoniness (NBSS& LUP Nagpur, 2021).

Management measures of soil

In order to reclaim the stony soils, addition of organic matter is to be done.Productive soil must brought in from other places in order to construct polyhouses. Cultivation of flowers like lavender, golden oats can be a good management.

1. Soil shallowness

Less than 50 cm is the solum depth in shallow soils. Over the parent material or bed rock, they typically have a thin 'A' horizon. In the event that the A horizon is underlying a B horizon, the combined depth of the two horizons cannot be greater than 50 cm. Parent rocks are found immediately below the soil's surface, at a depth of 15 to 20 cm, which is how shallow soils are generated. The shallow soil prevents the roots from spreading and elongating. Shallowness reduces the amount of soil that is accessible for full soil nutrients. They erode quite easily. Some very shallow soils might have developed from hard calcareous rock (Osman, 2018). In Himachal Pradesh 18.0 per cent area is affected with this problem (NBSS & LUP Nagpur, 1997; Forest Survey of India, 2017.).

Management:

a) Growing shallow rooted crops.
b) Frequent renewal of soil fertility
c) Growing crops that can withstand shallowness(Mango, country goose berry, fig, tamarind, ber and cashew etc)(Latha and Janaki, 2015).

2. Soil acidity

a) Soils become acidic when the concentration of H^+ exceeds that of OH^- ions.
b) Most of the acid soils are found in hilly terrains. These soils have been classified under the soil order Alfisols, Mollisols, Entisols and Inceptisols.
c) Himachal Pradesh consists of 33 per cent of acid soil region.
d) In Himalayan region, the brown forest soils, grey brown soils, brown Podzolicsoils come under acid soils.
e) In these soils, the concentration of H^+ exceeds that of OH^- ions. These soils contain large amount of soluble Al, Fe and Mn. A number of compounds contribute to the development of acid or basic soil reaction. Most of the acid soils are found in hilly terrains. These soils have been classified under the soil order Alfisols, Mollisols, Entisols and Inceptisols. In Himalaya region the brown forest soils, grey brown soils, brown podzolic soils come under acid soils (Mishra, 2004).

Sources of soil acidity

a) Leaching due to heavy rainfall
b) Acidic parent material and alumina silicate minerals
c) Acid forming fertilizers
d) Humus and other organic acids
e) Carbon dioxide and hydrous oxides
f) Acid rain

Management of acid soils

Management of the acid soils should be directed towards enhanced crop productivity either through addition of amendments to correct the soil abnormalities or by manipulating the agronomic practices depending upon the climatic and edaphic conditions (Latha and Janaki, 2010). Because lime enhances base saturation, P and Mo availability of acid soils while reducing toxicity of Al, Fe, and Mn, it has been acknowledged as an efficient soil ameliorant. Through increased microbial activity, liming also improves N mineralization in acidic soils and atmospheric N fixation. However, before making any recommendations, the economic viability of liming must be determined.

Liming materials for managing soil acidity

a) Lime material should be added to soil to rises its pH to some prescribed value.
b) Cultivation of such crops and plants which can grow in acidic soils. Eg. Apple, cauliflower, cucumber and corn etc. Commercial limestone and dolomite limestone are the most widely used amendments. Carbonates, oxides and hydroxides of calcium and magnesium are referred to as agricultural lime. Among, the naturally occurring lime sources calcitic, dolomitic and stromatoliticlimestones are important carbonates. The other liming sources are marl, oyster shells and several industrial wastes like steel mill slag, blast furnace slag, lime sludge from paper mills, press-mud from sugar mills, cement wastes, precipitated calcium carbonate, etc equally effective as ground limestone and are also cheaper. Considering the efficiency of limestone as 100per cent, efficiencies of basic slag and dolomite are 110 and 94 per cent respectively. Basic slag and press-mud are superior to calcium oxide or carbonates for amending the acid soils. Fly ash, a low- density amorphous ferro-alumino silicate also improves pH and nutrient availability.

Conclusion

Soils occurring in different physiographic regions are distinguished on the basis of soil properties and taxonomical classification. Therefore, this data can be utilized for sustainable land use planning for broad physiographical regions. In the state of Himachal Pradesh, four major soil orders are of great importance *i.e.*Entisols, Inceptisols, Alfisols and Mollisols.In HP, out of 55,673 sq km area, the 53.8 per cent area is affected by erosion, 23.1 per cent area is affected by stoniness, 22.8 percent area is not fit for agriculture due to rock outcrops and glaciers, and 33 per cent area is affected by acidic soil.Thus, cropping systems has to be adopted as per land capability for enhancing the economic yield and to maintain the soil health. These problematic soils require respective management practices in order to utilize full potential of the land and its sustainable use.

Conflict of interest statement

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this article.

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