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Soils in Hindu Scriptures *(including Jainism, Buddhism, and Sikhism)*

Tapas Bhattacharyya

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Chanakya University Research Monograph

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2023

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Preface

Soil is the foundation of life on Earth, and its significance in sustaining human civilisation cannot be overstated. The scientific study of soil has been a topic of interest for centuries, but humans' cultural and spiritual connections with soil are often overlooked. In this book, the portrayal of soil in Hindu scriptures, including Jainism, Buddhism, and Sikhism has been narrated.

Hinduism, one of the oldest religions in the world, has a rich tradition of emphasising the importance of soil as a sacred element of the natural world. The Vedas, Upanishads, Puranas, and other Hindu texts contain numerous references to the soil, its properties, and its role in human life. The Jain, Buddhist, and Sikh religions, which originated in the Indian subcontinent, also have deep-rooted connections with soil and its significance in their respective spiritual practices.

This book provides a comprehensive understanding of soil's cultural and spiritual significance in these religions. Various aspects of soil, such as its physical, chemical, and biological properties, and their role in agriculture and food production have been explored. It delves into the spiritual and cultural connections between soil and humans, including the use of soil in rituals, the symbolism of soil in mythology and folklore, and the ecological and environmental ethics, deeply embedded in these religions.

The content of this book might help readers with a comprehensive understanding of the role of soil in these religions and its impact on agricultural practices. It delves into the various religious texts and scriptures to highlight the importance of soil conservation, sustainable agricultural practices, and the role of soil in spirituality.

The book provides a unique perspective on soil and its importance in the spiritual and cultural traditions of Hinduism, Jainism, Buddhism, and Sikhism, which can help develop a more holistic and sustainable approach to soil management and deepen our appreciation of the natural world and its interconnectedness with human society.

I was guided to develop the outlines of this book by Drs S P Wani and K V Raju; later the themes and a few aspects were revised by Dr. Manasa R from the Chanakya University, Bengaluru.

Preparing a book of this magnitude requires tremendous support from many quarters. I have acknowledged almost all of them. A special note of thanks to the Chanakya University, Bengaluru, and the editorial staff for their help and cooperation. I fondly hope that this book may inspire readers to embrace a deeper respect and appreciation for the soil and incorporate these teachings into their daily lives.

Tapas Bhattacharyya
Ram Navami
30 March 2023
Nagpur

Contents

ABBREVIATIONS

APMCs	Agricultural Produce Marketing Committee
ACZs	Agro Climatic Zones
AERs	Agro-eco Regions
AESRs	Agro-eco Sub Regions
AD	anno Domini
BCSs	Bio-Climatic systems
BSR	Black Soil Region
B.C.	Before Christ
BCE	Before Christian Era
CWBRc	Correct Walkley-Black Recovery Factor
CGIAR	Consultative Group for International Agricultural Research
CE	Christian Era
DFI	Doubling farmers' income
DUs	Deemed universities
e-E	electronic extension
EO	expert opinion
FAO	Food and Agriculture Organization
FYM	Farmyard Manure
GIS	Geographic Information System
GDP	Gross domestic product
ICAR	Indian Council of Agricultural Research
IT	Information Technology
ISLTFE	Information System on Long Term Fertilizer Experiment
ICT	Information & Communication Technology
IARI	Indian Agricultural Research Institute
IVRI	Indian Veterinary Research Institute
IGP	Indo-Gangetic Plains
IVC	Indus Valley Civilization
LDN	Land degradation neutrality
LTFE	Long-term fertilizer experiments

NRM	Natural Resource Management
NGOs	Non-governmental organizations
NARS	National Agricultural Research System
NAEP	New Agricultural Education Policy
NEP	National Education Policy
NDRI	National Dairy Research Institute
NSSO	National sample survey office
OC	Organic Carbon
RDF	Recommended Dose of Fertilisers
SAUs	State Agricultural Universities
SOC	Soil Organic Carbon
SIC	Soil Inorganic Carbon
SOLAQ	Soil and Land Quality model
SIS	Soil information system
SIT	Soil information technology
SAT	Semi-arid Tropics
SDG	Sustainable Development Goals
SQ	Soil quality
SSSA	Soil science society of America
SQI	Soil Quality Index
UN	United Nations
WSD	World Soil Day

Soils in Hindu Scriptures (including Jainism, Buddhism, and Sikhism)

Tapas Bhattacharyya

Abstract

Hinduism is considered unique in the world of religions since it had no founder yet grew gradually over five thousand years, absorbing, assimilating, and guiding all other faiths to bear the cultural heritage of India. Hinduism has no Bible/Koran/Dhammapadam to find potential solutions for problems. Hinduism clarifies the differences and shared beliefs of different schools of thought within it, thus resembling Christianity binding human civilization with a common thread. There is no historical creator of Hinduism as in Jainism, Buddhism, and Sikhism.

According to the literature (Hindu text, the Bhagvad Gita), relationships of human/nature (yagna), human/divine (tapas), and human/human (dana) are conceptualized to stitch human beings and nature through soil, soul, and society. This suggests a high level of realization to connect these three to have a harmonious relationship with nature and sustain human civilization. All religions address soils differently and portray diverse cultural patterns of understanding this valuable natural resource. According to Hindu religious belief, soil (matter, nature) is considered divine and respected as Mother. Soil is seen as a feminine donor, attributed predominantly to chthonic (Ancient Greek word: khthon, which means earth or soil). In Hinduism soil is referred as dharti/bhoo mata: Mother Earth is also related to cosmic elements. In Buddhism, the soil is described as a symbol of dust in this ephemeral world to support life.

Humans belong to nature, and when they cultivate soil, it always reverberates in their mind. To relate humans with soils, two different types of religious concepts, namely natural religion and salvation religion are postulated. During the long history of human civilisation with primal religion (Primal religion has a priority where the fundamental aspect of religion is available). Being dominant, the soil is considered supernatural and controlled by an unseen power. Soils are part of religious reverence, justifying certain rituals to sustain their fertility.

However, the modern-day approach to soils takes environment, ethics, and ecology as more essential aspects. Human ecology is related to human concepts of nature and destiny (religion). Hindu religion always considers land/soil as mother earth, cautioned about its use and abuse, and recommends its preservation for posterity. Given this, Hinduism and other religions such as Jainism, Buddhism, and Sikhism and their concepts indirectly believe in the environment and ecological sustenance. They are in line with the modern-day vision.

1. Introduction

Hinduism is one of the major religions with 1030 million followers (Table 1). It is one of the world's oldest religions (Kurien, 2006), though its specific period of birth is unknown. Agriculture is a significant professional activity of people in the rural areas of India (Aubron, 2015) and includes many activities (Kissa and Matsoukis, 2019). Agriculture seems to have been significantly influenced by Hinduism throughout the ages, taking into account that Hinduism has influenced the daily lives and beliefs of the Indian people (Deshpande, 2010).

This may be because food and (agri)culture have one thing in common and that is religion. This is notwithstanding the fact that many religions forbid a few food items. Soils are the source of energy since it provides food for all for sustenance. It seems logical that human beings always felt hungry before religion. Soils (and their management) used for the agricultural purpose to grow crops to meet the hunger of people, came later. Soil, as a source of food and religion, people followed, thus, making an interesting discussion.

Difference of opinion exists regarding the beginning of religion and agriculture (synonymously taken as soil/ soil management). Many people think religion came before agriculture since many hunter-gatherers used to pray to their god for luck in hunting (Anonymous, 2022a). Agriculture dates back to the Neolithic era (7000-10000 years ago), whereas religious behaviour existed during the Upper Palaeolithic era (~30000 years ago). The first evidence of spiritual experience representing religion is still older; it is from the Lower Palaeolithic era (~300,000 years ago).

People realized the importance of soil and, since then started concentrating on agriculture and settling down to live a community life. For Hindus, their religion taught them to worship soil as mother earth. This went on for generations, with dynasties facing ups and downs in the society/kingdom for thousands of years. Mention of soil in Hinduism, through local beliefs, Sanskrit shlokas in different Hindu scripts, and folk songs to maintain soil/land conditions is available in the literature.

Hinduism has been described as a way of life. Hindus carried out agriculture to maintain soil health through an appropriate dose of manuring at the right time, choosing the right crop at the right season. It did help to preserve the ecology for longer sustenance, and they passed on such knowledge through generations.

There should be a high level of reverence for mother earth. With the help of the spiritual flavour in life, the mind will become purely devoted to mother earth (soil) and selfless. Hinduism teaches about the way to live in harmony with nature

to make our life comfortable and to leave a better earth for the next generation -- highlighting the principle of sustainability thousands of years back. A very popular mantra, from our ancestors, shows magnanimity and broad-mindedness to seek peace for all. And that is perhaps the mantra of Hinduism as shown below.

ॐ सर्वे भवन्तु सुखिनः
सर्वे सन्तु निरामयाः ।
सर्वे भद्राणि पश्यन्तु मा कश्चिद्दुःखभाग्भवेत।
ॐ शान्तिः शान्तिः शान्तिः ॥

oṃ sarve bhavantu sukhinaḥ
sarve santu nirāmayāḥ
sarve bhadrāṇi paśyantu mā kaścidduḥ khabhāgbhaveta |
oṃ śāntiḥ śāntiḥ śāntiḥ ||

May all sentient beings be at peace, may no one suffer from illness,
May all see what is auspicious, may no one suffer. Om peace, peace, peace.

With the burgeoning population over time in the present day, on the one hand, and grossly ignoring the National Agricultural Research System (NARS) recommendations, people started thinking about the future of the soils and their management. All such information has been collated in the following sections. Efforts are made to show the sources of information in most cases. Hinduism is a vast subject and linking it with soil, in many cases, has been less rewarding. Mention has, therefore, been made indirectly; in many cases, general agriculture has been related to soils.

Sincere efforts are made to show that this subject could be enchanting and rewarding for students, professors, and many other experts in the field of religion to further this knowledge to make our life safe and peaceful. All attempts are made to include most of the issues; lapses, if any, are purely unintentional.

2. Religions

Globally, more than an estimated 4,000 (Anonymous, 2022b) to 4020 (Anonymous, 2022c) religions exist. These religions have different geographical locations, languages, founders, and beliefs (Table 1) and different populations (%) of followers (Figure 1).Only a few are discussed here.

Soils in Hindu Scriptures

Table 1: A few selected religions existing in the World

Religion	Age	Features	Origin and Religious heads	Holy Book
Hinduism	15th to 5th Century BCE	Oldest religion in existence, belief in the Vedas	Indian subcontinent	The Vedas, The Puranas, The Ramayana and Mahabharata
Zoroastrianism	10th – 5th century BCE	Indo-Iranian religion, Abrahamic tradition	Persian empires	The Avesta
Yazdânism	Old/older than Zoroastria nism	Oldest monotheism, ancient Egyptian faith called Atenism, and two successor faiths – Christianity (1st century CE) and Islam (7th century CE)	Kurdish and Belgian scholar Mehrdad Izady, a mix of Islam and a Hurrian precursor	The Kalâm-e Saranjâm

Judaism	9th – 5th century BCE	Oldest monotheism, ancient Egyptian faith called Atenism, and two successor faiths – Christianity (1st century CE) and Islam (7th century CE)	Israel and Judah	The Torah
Jainism	8th – 2nd century BCE	Tirthankaras, omniscient preachers of the Jain path, asceticism, and self-discipline	Ancient India, Aadinatha, first Tirthankara, Mahavira	The Agamas
Confucianism	6th – 5th century BCE	Chinese folk tradition, Heaven, the Lord on High, and divination	Confucius, China	"The Book of History," "The Book of Poetry," "The Book of Changes," "The Book of Rites," and the "Spring and Autumn Annals."
Buddhism	6th – 5th century BCE	Buddha, Dharma, Sangha, four noble truths, eightfold path, nirvana, monastic code, and meditation techniques	Siddhartha Gautama (Lord Buddha), India, Nepal	The Tripitaka or Pali Canon

Taoism	6th – 4th century BCE	God-like Yellow Emperor, traditional Chinese folk religion, contemporary of Confucius	Operation of the natural world, the process of life, China	The Tao Te Ching
Shintoism	3rd century BCE – 8th century CE	Ancient Japanese mythology, Buddhist influences	Japan	the Kojiki or 'Records of Ancient Matters (712 CE) and the Nihon-gi or 'Chronicles of Japan' (720 CE)
Christianity	1st century CE	God the Creator, God is everywhere, Humans are the most important in God's creation	Jesus Christ, Israel, and Palestine	The Bible
Islam	7th century CE	Allah is self-existent, He is beyond all types of boundaries and limitations (time and place)	The prophet Muhammad	The Quran

Sikhism	15th century CE	Nam Marg, Deg (community kitchen, Langar), Teg (sword, power, preserve tyranny) Fateh (victory)	Guru Nanak (1469–1539)	The Guru Granth Sahib
Bahá'í	mid-19th century	Unity of the major world religions, single, inaccessible, omniscient, omnipresent, and almighty God	Mīrzā Ḥosayn ʿAlī Nūrī (Bahá'u'lláh; Arabic: "Glory of God")	Kitáb-i-Aqdas (The holiest book)
Folk Religion *	-	Ethnic or regional religious traditions	-	-

*Largest folk religion in the world is the Chinese folk religion Sources:

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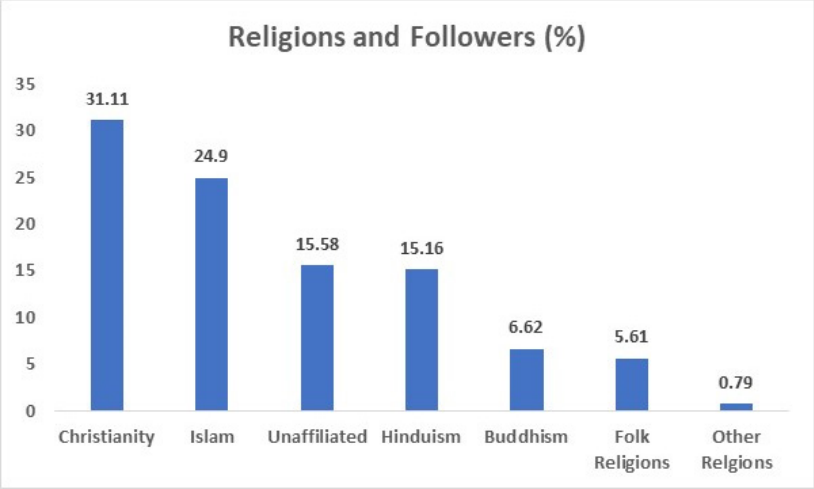

Figure 1: Selected world religions and the followers (%) (Source: Anonymous, 2022a https://www.bing.com/search?q=how+many+religions+are+in+world%3F&go=Search&qs=ds&form=QBRE)

2.1 Hinduism

Hinduism rests on numerous textural scripts and covers a vast number of sectarian creeds (Nirvedananda, 1944). Hinduism, as a religion, has nothing to fear from any advance in scientific knowledge and/or historical criticism. Many millions of years ago, people had very limited knowledge about the exactness of religion or sect (Sen, 2019). Religion means a system of faith and worship. Hinduism is a synthesis of elements derived from several directions and incorporates every conceivable motive of religion (Nivedita and Coomaraswamy, 1913). The motives of the Hindu religion include worshipping the earth, sun, nature, sky, and ancestors, including parents, plants/trees, and animals.

In ancient days Hinduism was known as Arya dharma, and the followers were Aryan. Their home, it is said, was in Punjab, although there are other opinions (Nirvedananda, 1944). History has always strived to systematise all forms of belief and in such attempts, many books, known as Puranas (Nivedita and Coomaraswamy, 1913) like the Ramayan[1] and Mahabharat[2] were written. Our predecessors were fortunate and could educate the next generations about their existence through the Vedas[3] (Vedic Era - The Aryans – 2500 B.C.) and Upanishads[4] which gave existence to Hinduism through Vedic Samhitas composed mainly in the second millennium BCE. This provides a route to theories of existence and life which we find in the Upanishads (800 BC) (Sen, 2019). Other than Hinduism, every religion tends to find a difference between what a man does and according to values what he ought to do? This difference is quite connected with man's concept of the nature of the universe (Sen, 2019). Today, we are fortunate enough and feel much more secure than our predecessors regarding social life and social harmony. Modern scientific techniques and social evolution connect us and constitute a challenge as well as an opportunity. Hindu society or Hinduism consists of many cultures and races. The term Hindu is derived from the river Sindhu[5] (Indus), for the Persians referred to India as the land beyond the Sindhu (Thapar, 2022).

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[1] Ramayan (9300 BP): A Sanskrit epic from ancient India and an important legend of Hinduism. The epic, traditionally ascribed to the Maharishi Valmiki, narrates the life of Rama, a legendary prince of Ayodhya city.

[2] Mahabharat (3300 – 2600 BCE): A Sanskrit epic of ancient India which describes the struggle between two groups of cousins in the Kurukshetra War and the fates of the Kaurava and the Paṇḍava princes and their successors.

[3] Vedas: These are a collection of hymns, philosophy, and guidance of religious texts written in Vedic Sanskrit and represent the oldest scriptures of Hinduism.

[4] Upanishads are philosophical religious texts of Hinduism.

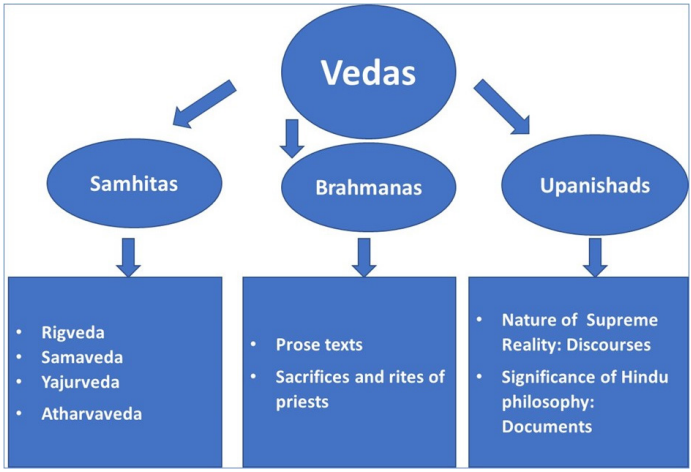
[5] Sindhu (Indus): A river at present is a transboundary river of Asia and a trans-Himalayan River of South and Central Asia.

After the Harappan Age[6] , it was the era of the Aryans, who used to speak a different language which we know as Sanskrit according to the Rigveda[7] . The religion the Aryans used to follow is quite similar to the Harappan Civilization. They used to worship nature. The evidence says that a Shivalinga[8] was found in the land of Harappa. But they worshipped it not as Lord Shiva but as yoni (womb) and linga (bearer) (Basham, 2004). Two symbolic processes (creation and regeneration by the union of male and female principles) are represented by yoni and womb, signifying the existence of the whole universe. Similarly, Aryans also worshipped nature which included the sun, moon, fire, and storms.

Researchers say that the Harappan age had a downfall because the Aryans invaded them. People opine that the Aryans had better military equipment and more martial traditions. Some evidence has a close affinity to Pashupati Siva of the Hindu religion. Through all this, we can imagine and be quite confident that in those ancient times, some fusion between Vedic and pre-Vedic cultures took place in India.

The Vedic age has a significant contribution to forming the Hindu religion. It has a decisive influence on the trend of Indian culture. Vedic religion, also known as Vedism is the oldest stratum of religious activity. Veda is defined as knowledge (Anonymous, 2022d) consisting of three parts such as Samhitas, Brahmanas, and Upanishads (Figure 2).

Figure 2: **The Different parts of the Veda and their features**



[6]Harappan Age: The earliest Harappan sites date to 3500 BCE.

[7]Rigveda: It is an ancient Indian collection of Vedic Sanskrit hymns.

[8]Shivalinga: It is an abstract or aniconic representation of the Hindu God Shiva.

A. Samhitas

Saṃhita is conjugation of two parts of a Sanskrit word meaning sam (together), and hita (meaning good). It refers indirectly to 'put together/ joined' which agrees or conforms to a principle such as dharma in accordance with justice. It consists of the following:

- **Rigveda**

The Rigveda or Vedas are made of several verses numbering nearly 1000 hymns. These hymns were composed to address different deities. Since the priestly families were thought of maintaining the sanctity of the sacred verses, these hymns were meant for those families.

- **Samaveda**

The Samaveda or Vedas of Chants consists of a selection of verses drawn almost wholly from the Rigveda. These musical chants were characterized by the accompanying notations to sing these sacred songs.

- **Yajurveda**

The Yajurveda represents the Vedas of Sacrificial Formulas. These formulas signify different proses which are used for different rites.

- **Atharvaveda**

It's a later compilation that includes incantations and magic spells.

B. Brahmanas

Brahmanas or Brahminism emphasised the rites performed by and the status of the Brahmana, or priestly class as well as speculation about Brahman as theorised in the Upanishads.

C. Upanishads

The Upanishads are the philosophical, religious texts of Hinduism (also known as Sanatan Dharma[8]) which develop and explain the fundamental tenets of the religion. It deals with ritual observance and the individual's place in the Universe (Anonymous, 2022e).

[8] Sanatan Dharma: It defines the eternal order or eternal path.

D. Other characteristics of Hinduism

It seems, in this age of science, the present generation is fortunate as compared to their predecessors. Modern science and its developmental effects, if linked to Hinduism and its basic understanding, might address many of our challenges and opportunities. Although, Hinduism may not answer all the perplexing situations, yet it may resolve a few through its fundamental beliefs and philosophy.

Explaining the basics of Hinduism poses a difficulty since many of its terms do not have exact synonyms (Sen, 1961). The definition of Hinduism is another challenge. As Sen (1961) illustrates

"Hinduism is more like a tree that has *grown* gradually than like a building that has been erected by some great architect at some definite point in time"

Hindu thoughts have evolved through various stages and cultures of the Dravidian, Sanskritized Aryan culture, Buddhism, Jainism, Sikhism, Islam, and Christianity. While mentioning in his Comparative Religion (Bouquet, 1956) it is noted that

"India, in particular, furnishes within its limits examples of every conceivable type of attempt at the solution of the religious problem."

In the second millennium BCE, Aryans arrived in India; their language gave rise to Sanskrit in their religion and was presented in the Rigveda (Sen, 1961). There are some commonalities in the texts of the Vedas and their European counterpart (like Vedas with the Iranian Avesta; the Vedic god of the sky Dyans is like the Greek Zeus, the Latin Jupiter; the Hindu God Mitra is the same as the Iranian Mithr: Sen, 1961). The philosophies of the Upanishads, the Gita[9], and the Dhammapada[10] help teach the Hindu philosophy to understand life. Hindu doctrines recommend an ideal life to be considered of four ashramas (stages). These are brahmacharya (stage of discipline and education), grihastha (household and active work), vanaprastha (retreat and withdrawal from various bonds), and sannyasa (life of a hermit,

[9]The Gita: The Shrimad Bhagavad Gita often referred to as the Gita, is a 700-verse Hindu scripture that is a part of the epic Mahabharat, dated to the second half of the first millennium BCE, and is typical of the Hindu synthesis. It is considered to be one of the holy scriptures of Hinduism.

[10]The Dhammapada is a collection of sayings of the Buddha in verse form and one of the most widely read and best-known Buddhist scriptures.

sannyasi). The Hindu system of active work includes knowledge, sacrifice, helping others (service), and retreating from mortal life (worldly success) for renunciation. The Hindu caste system invites more discussion since it has been developed out of the multiracial nature of Indian society. Hinduism is a confluence of many cultures, and there is a scope of celebrations through numerous festivals, which take place weekly, monthly, annually, and regionally. The festivals involve worshipping gods, and goddesses following a change of season, astronomical positions, birth, marriages, and other social commitments in various religious places or at home.

The Hindu religion is hospitable, absorbent, tolerant, and unifies people. It accepts the omnipresence of God. It takes several paths to reach God. Recognition of many paths, each valid in itself, makes Hinduism tolerant of various people. Hinduism is free to select the way to worship and reach God through work (karma), meditation, and knowledge (gyan), or the path of bhakti (devotion). In the Bhagavad Gita (Fourth Lesson, verse 11), The Lord, in the form of Krishna, declares

ये यथा मां प्रपद्यन्ते तांस्तथैव भजाम्यहम् |
मम वर्त्मानुवर्तन्ते मनुष्याः पार्थ सर्वशः || 11 ||

ye yathā mām prapadyante tāns tathaiva bhajamyaham
mama vartmanuvartante manushyaḥ pārtha sarvashaḥ

"As all surrender unto Me, I reward them accordingly.
Everyone follows my path in all respects, O son of Pritha"

An Indian archaeologist found an ancient knife in Mohenjo-Daro (mound of the dead) in 1917 at Larkana valley of Sind, which throws light on the pre-Vedic cultures. In 1922, diggings discovered some stone seals identical to those found in another site called Harappa[11] . An organised communal living, dating 2500 BCE in this Indus valley civilization, revealed the use of metals (iron and gold), foodstuffs (wheat, barley, meat, fish, and fruits), weaving materials (cotton), streets, and a drainage system. It was clear that Hindu customs [use of sindoor (vermilion), and shankah (conch shell bangles)] came from these people (Sen, 1961).

[11]Harappa: Harappa is an archaeological site in Punjab, Pakistan, west of Sahiwal. The Harappan Civilization has its earliest roots in cultures such as that of Mehrgarh, approximately 6000 BCE. The two greatest cities, Mohenjo-Daro and Harappa, emerged circa 2600 BC along the Indus River valley in Punjab and Sindh.

The Vedas mean the Vedic Samhitas, which are collections of prayers and rituals. The Hindus persist in thinking of their religion as being according to the Vedas and in looking upon the Vedas as the embodiment of revealed literature. The Vedic gods are inspired by Nature such as the sun, the moon, fire, sky, storm, air, water, dawn, and rain. One of the Vedic mantras which make a part of daily worship is the Gayatri Mantra (Rigveda, 3, 62, 10) which means

Let us contemplate the wondrous spirit of the Divine Creator (Savitri) of the earthly, atmospheric, and celestial spheres. May He direct our minds 'toward' the attainment of dharma, artha, kama, and moksha,

Om.

ॐ भूर्भुवः स्व तत्स वितुर्वरेण्यं भर्गो देवस्य धीमहि
धियो यो नः प्रचोदयात् ॥

oṃ bhur bhuvaḥ svah tat savitur varenyam bhargo devasya dhimahi
dhiyo yo nah pracodayāt

The Vedas were not written down for ages, and the texts were transmitted through generations due to remarkable memories of the priests and teachers through the custom of ***parampara*** from the ***gurus*** (master/teacher) to the ***shishyas*** (disciples). Among many races of India, some are worshippers of a river, a mountain, or a tree/ animal. Each of these cults has influenced Hinduism (Sen, 1961).

2.2 Jainism

During the heterodoxy, when religious leaders were defending the existence of God, Jainism and Buddhism were born. Interest in man and human beings got better than other aspects of worship. There was an environment of intellectual experimentation when Jainism and Buddhism arose by the Kshatriya leaders, unlike Vedic Brahmins.

Jainism (8th-2nd century BCE) (Table 1) believes in twenty-four teachers of Tirthankaras[12] before Mahavira to consolidate this religion. Jain ethical code prescribes two dharmas or rules of conduct. One for those who wish to become

[12] Tirthankara: Tirthankara (is a saviour and spiritual teacher of the dharma (righteous path) in Jainism. A Tirthankara is an individual who has conquered the saṃsāra, the cycle of death and rebirth, on their own, and made a path for others to follow. After understanding the true nature of the self or soul, the Tirthankara attains Kevala Jnana (omniscience). Tirthankara provides a bridge for others to follow the new teacher from saṃsāra to moksha (liberation).

ascetic and another for the śrāvaka (house holders). Five fundamental vows are prescribed for both votaries. These vows are observed by śrāvakas (householders) partially and are termed anuvratas (small vows). Ascetics observe these five vows more strictly and, therefore, observe complete abstinence. These five vows are:

1. Not to kill
2. Not to speak untruth
3. Not to steal
4. Continence
5. Renunciation of pleasure in external objects.

Jainism is prevalent in many parts of India, including Gujarat, Rajasthan, Madhya Pradesh, Maharashtra, South India, and some portions of West Bengal. In the western part of India, the patrons of this faith were mainly from the trading community. Since they were forbidden from agriculture for fear of injuring soil-borne creatures, they forced other types of trade and commerce (Roberts, 1993; Thapar, 2002). The vegetarianism of some sects of Hindus might be due to the influence of Jainism. An essential feature of Jainism is its part in the growth of medieval mysticism. Jainism started with simple faith, devoid of pandits/priests or rules. However, later it was influenced by those rules.

2.3 Buddhism

Buddha Dharma (6th-5th BCE) (Table 1) preached by Lord Buddha taught his disciples the basic tenets, including the doctrine of the Middle Path (avoiding extremes), non-violence, non-hatred, friendliness to all, renunciation, continence and attaining nirvana, the freedom from the cycles of births. To achieve this, he advised the Eight-fold path (https://www.learnreligions.com/the-eightfold-path-450067) (See the Box below) of moral and spiritual improvement. Buddhism was the state religion in the 3rd century BCE at the time of Emperor Ashoka.

1. Right view or Right Understanding: Insight into the true nature of reality
2. Right Intention: The unselfish desire to realize enlightenment
3. Right Speech: Using speech compassionately
4. Right Action: Using ethical conduct to manifest compassion
5. Right Livelihood: Making a living through ethical and nonharmful means
6. Right Effort: Cultivating wholesome qualities and releasing unwholesome qualities
7. Right Mindfulness: Whole body- and mind-awareness
8. Right Concentration: Meditation or some other dedicated, concentrated practice

Box. Eightfold path to enlightenment in the Buddhism

Buddhism sidestepped the Brahminical religion and offered importance to the role of women to low-caste followers since caste was irrelevant to His thoughts (Roberts, 1993). Buddhism contributed most to Indian culture through education. Under this religion, various universities grew in India, of which the Nalanda was the important one. The Jatakas, a part of Buddhist canonical literature, signifies the heavenly pearls of wisdom of the Lord Buddha himself (Anonymous, 2022 f). The Jataka tales teach about wisdom to influence many for a long time not only in India but also in others. The Jataka stories, related to animals, are the inspiration for French literature also. Lord Buddha used to narrate the stories of the past to teach the correct path to follow to his disciples. It is stated that a total of 547/550 Jatakas are in existence. Lord Buddha's insights into the natural laws governing the universe are the Jataka tales. Most of the Buddhist structures narrate the Jataka

stories indicating their popularity. Depictions of the Jataka can be seen in Madhya Pradesh, Andhra Pradesh (Nagarjuna Konda in Guntur district), the shrines at Sanchi and Amravati, Goli in Andhra Pradesh, Nalanda and Mathura, Boro-Budur in Jawa, and Sukhodaya in Siam, and Pagan in Burma.

2.4 Sikhism

It is a religion founded by Guru Nanak in the late 15th century in India (Table 1). The word guru means teacher, and the term Sikh has its origin in the word shishya, meaning disciple or student. Guru Nanak was the first Sikh guru. There were nine gurus after him. The fifth Sikh guru, Arjun, wrote down his hymns and of the earlier gurus. The last guru, Gobind Singh, added his hymns. He advised that the book with hymns should be considered the holy book of the Sikhs. This is known as ***Adi Granth*** or ***Granth Sahib***.

Sikhs call their place of worship Gurudwara (gateways to the Guru). The chief Gurudwara is the Golden Temple built in Amritsar, India. Sikhs eat together in the Gurudwara as a sign of the equality of all kinds of people.

A devout Sikh follows both personal and panthic, or communal, elements. For a Sikh, the secular life (Miri) incorporates standards of spiritual living (Piri). The Sikhs follow Gurmat the principles taught by the ten gurus over three centuries. It is customary for a Sikh to stick to the Sikh code of conduct from birth till death. Sikhs, when they meet like-minded company, greet one another by saying,

Waheguruji ka Khalsa (Khalsa belongs to God)

Waheguruji ki Fateh (Victory belongs to God).

(Anonymous, 2022g)

Sikhism follows a different concept of God (Ik Onkar meaning One constant) compared to other religions. God is represented by two concepts such as Akaal Purkh (as beyond time and space) and Nirankar (without form). Guru Gobind Singh (the last Guru of the Sikhs) created the Khalsa, which depicts the spiritual brotherhood and sisterhood and is devoted to purity of thought and action. The Khalsa has a distinctive external form to remind them of their commitment and to help them maintain an elevated state of consciousness. Every Sikh baptised as Khalsa vows to wear the Five "Ks" – Kesh, Kangha, Katchera, Kara, and Kirpan. A Sikh's public life and responsibilities include obligation (to serve the collective consciousness community of Sikhs), initiation (duty to live as a committed member of the Sikh Community), discipline (to reprimand for default of commitments of Initiation), fundamentals (to live according to Sikh principles), and appeals (to Akal Takht, Religious Authority for all Sikhs) (Anonymous 2022h).

3. Hindu scriptures: Mythological anecdotes (with examples)

3.1 Hindu Scriptures

Hindu scriptures always refer to reinforce the major concept of Hindu environmental thought:

All is God, all is Divine, all is to be treated with reverence and respect, and all is sacred.

The very concepts which build this belief system include Vasudeva sarvam (the Supreme resides in all beings); Vasudhaiva kutumbakam (the family of Mother Earth, the concept of the global village, at that point of time); and Sarva bhuta hita (the welfare of all beings) (McDermott, 2009).

There are many scriptures in the Hindu religion; the major Hindu scriptures and their chronology are shown in Figure 3. Scripts are found as pictorial signatures as seals, tablets and different art forms of potteries and characterize the Indus civilization (Mishra,2001). Miniature animal figures may be seen as a master craftsmanship of earlier people engraved on seals (Figure 4). Recently a short inscription of large letters has been discovered on the floor of a structure at Dholavira (Figure 5) (Anonymous, 2022a,i). These signs are very small and vary between five (minimum) to seventeen (maximum). The script was written from right to left. For more than one-line script boustrophedonic style of writing (one line is written from one direction and the other one from the opposite direction) was followed. The script is uniformly observed in a vast area and the long duration of the civilization. The writings were deciphered by various claimants; acceptance of archaeologists and linguists was, however, not received (Parpola 1994; Possehl 1996).

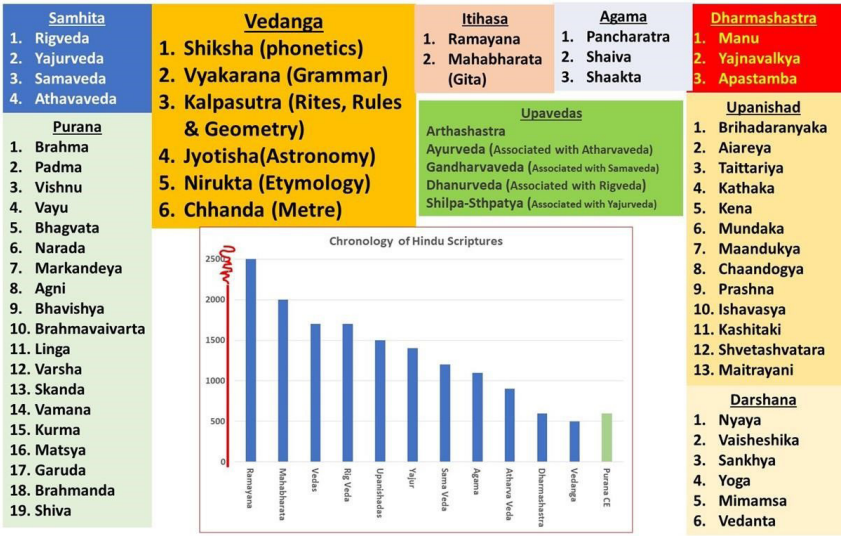


Figure 3: Figure 3. The major Hindu Scriptures and their chronology (Source: https://www.quora.com/What-is-the-list-of-all-Hindu-scriptures; Ramayana how old in BCE? - Search (bing.com); Mahabharata how old in BCE? - Search (bing.com); How old is Agama? - Search (bing.com); DHARMASHASTRA (c. 600 B.C.—c. 200 A.D.) Gautama SutraApastamba SutraVasishtha SutraLaws of ManuVishnu Smriti | The Ethics of Suicide Digital Archive (utah.edu); How old is Vedanga? - Search (bing.com); How old is Purana? - Search (bing.com)).

Figure 4: The seal in the Indus Civilization: Earth is mysterious (Source: Anonymous 2022j)

Figure 5: Interpreting the Dholavira Sign Board of Indus Civilization (a) Picture of the signboard as found in Dholavira; (b) A line drawing of the symbols inscribed in Figure (a) Number of symbols on the signboard: 10 (Symbols 8 and 9 are read as one unit as they are twin representations).

The symbols say a lot about all the rituals that were in vogue during the Vedic and post-Vedic periods(Figure 5). Symbol reading from left to right:

1. Gārhapatya – the Circular symbol with 6 spokes, one of the 3 sacred altars.
2. The Praṇītāh Pātra – a kind of cup with a handle. (maybe about Cāturmāsya rituals),
3. Daśāpavitra- the filter used in soma yajna,
4. The symbols of the Gārhapatya altar,
5. Āhavanīya, the square-shaped altar, one of the three sacred fire altars,
6. The Catuṣpatha symbol where 4 roads meet, where oblation is offered to Rudra,
7. Idhma, a single stroke may indicate the supply of wood logs required for the sacred hearths and maintenance of fire daily,
8. Punarādheya, the two Gārhapatya symbols indicate– the reinstallation of sacred fires,
9. Punarādheya, the two Gārhapatya symbols indicate– the reinstallation of sacred fires,
10. Pariśasa -the symbol of the tongs used in Pravargya, an independent fire ritual

Anonymous, 2022i, https://indiafacts.org/interpreting-the-dholavira-sign-board-of-induscivilization/

The Upanishad does not distinguish between the world we perceive and the Divine. Rather than being created out of a separate substance, the universe and everything within it, the planet we inhabit and everything upon it, are emanated from the Divine. The process of creation is analogous to a spider creating its web, as shown below, which means

"As the spider sends forth and draws in its thread, as plants grow on the earth, as hair grows on the head and the body of a living man, so does everything in the universe arise from the Imperishable" (The Mundaka Upanishad[13] 1.1.7).

यथोर्णेनाभिः सृजते गृह्णते च
यथा पृथिव्यामोषधयः सम्भवन्ति ।
यथा सतः पुरुषात् केशलोमानि
तथाऽक्षरात सम्भवतीह विश्वम् ॥ ७॥
yathorṇenābhiḥ sṛjate gṛhṇate ca
yathā pṛthivyāmoṣadhayaḥ sambhavanti
yathā sataḥ puruṣāt keśalomāni
tathākṣarāt sambhavatīha viśvam ||7||

The Brihadaranayaka Upanishad[14] (2.5.1) speaks of creatures and creation, which carries the meaning as

'This earth is (like) honey to all beings, and all beings are (like) honey to this earth. The same with the shining immortal being who is on this earth, and the shining, immortal, corporeal being in the body. These four are but this Self. This (Self-knowledge) is (the means of) immortality; this (underlying unity) is Brahman; this (knowledge of Brahman) is (the means of becoming) all.' (The Brihadaranayaka Upanishad 2.5.1) (Anonymous 2022k).

इयं पृथिवी सर्वेषां भूतानाम् मधु,
अस्यै पृथिव्यै सर्वाणि भूतानि मधु;
यश्चायमस्यां पृथिव्यां तेजोमयोऽमृतमयः पुरुषः,
यस्वायमध्यात्मं शारीरस्तेजोमयोऽमृतमयः पुरुषः,
अयमेव स योऽयमात्मा; इदममृतम्,
इदं ब्रह्म, इदं सर्वम् ॥ १ ॥
Iyam pṛthivī sarveṣāṁ bhūtānām madhu,
asyai pṛthivyai sarvāṇi bhūtāni madhu;
yaścāyamasyāṁ pṛthivyāṁ tejomayo'mṛtamayaḥ puruṣaḥ,
yasvāyamadhyātmaṁ śārīrastejomayo'mṛtamayaḥ puruṣaḥ,
ayameva sa yo'yamātmā; idamamṛtam,
idaṁ brahma, idaṁ sarvam. || 1 ||

[13]The Mundaka Upanishad: It is an ancient Sanskrit Vedic text, embedded inside Atharva Veda and is a Mukhya (primary) Upanishad.

[14]The Brihadaranayaka Upanishad is one of the Principal Upanishads and one of the first Upanishadic scriptures of Hinduism.

3.2 Soils and mythological anecdotes (with examples)

There are many anecdotes of ancient ages making mention of soils/earth for their usefulness and preservation for humankind. A few are mentioned here.

3.2.1 Soils/earth in Hindu scriptures

There are references to soils in ancient Hindu literature, and in many cases, earth or Mother Earth is also mentioned, which appears synonymous with soils.

Ether, air, fire, water, earth, planets, all creatures, directions, trees and plants, rivers and seas—they all are organs of God's body. Remembering this, a devotee respects all species. SRIMAD BHAGAVATA MAHAPURANA (2.2.41)

3.2.2 Atharva Veda and earth

One of the hymns in the Atharva Veda was addressed to the goddess Earth. It showed how the ancients approached this subject of present-day global warming and other related subjects. A ***shloka*** dedicated to Mother Earth, from ***Bhoomi Sukta, Atharva Veda,*** speaks about the truth and the cosmic Divine law (Figure 6) (Anonymous 2022k).

Mother Earth

सत्यं बृहदृतमुग्रं दीक्षा तपो ब्रह्म यज्ञः पृथिवीं धारयन्ति ।
सा नो भूतस्य भव्यस्य पत्न्युरुं लोकं पृथिवी नः कृणोतु ॥ १॥

-भूमि सूक्त, अथर्ववेद १२.१

Rough translation

(Salutations to Mother Earth) The Truth (Satyam), the Cosmic Divine Law (Ritam). the Spiritual Passion manifested in Mighty Initiations, Penances and self dedications to the search of Brahman (by the sages); these have sustained the Mother Earth for ages (Who in turn have supported these in Her Bosom). She, the mother Earth, Who is to us the Consort of the Past and the Future (being its witness). May She expand our inner life in this World towards the Cosmic Life (through Her Purity and Vastness).

Figure 6: A Shloka dedicated to Mother Earth, from Bhoomi Sukta, Atharva Veda

The Earth is stably supported by the truth, greatness, universal order, strength, consecration, creative fervour, spiritual exaltation, and sacrifice. The Earth, the mistress of that which was, and shall be, is earnestly requested to prepare for us a broad domain. The earth has heights, slopes, and Great Plains, which support the plants. There is a request to the earth to spread out for us and fit herself for us for accommodating her children. The Earth is also requested to pour milk for us in rich streams and bestow us with glory and snowy mountain heights. The

forests are also requested to be kind to us as is mentioned here.

"The mortals born of thee live on thee, thou supported both bipeds and quadrupeds. Thine, O Earth, are these races of men, the mortals upon whom the rising sun sheds undying light with his rays. All of us are your subjects. May all of us live together in harmony" (Figures 7 and 8).

विश्वस्वम् मातर्मोषिधिनां ध्रुवां भूमिं पृथिविं धर्मणा धृताम् |
शिवां स्योनामनु चरेम विश्वहा ||17 ||
viśvasvam mātarmoṣidhināṁ dhruvāṁ bhūmiṁ pṛthiviṁ dharmaṇā dhṛtām |
śivāṁ syonāmanu carema viśvahā ||17||

Let the Mother Earth be stable and broad Upon which the best of Medicinal plants grow. Let us serve the Motherland, The Mother Earth who bestow us with means of material pleasure which are full of Knowledge,Bravery, Truth, Love and other good qualities.

Figure 7: The Atharvaveda. The 63rd verse on the stability of Mother Earth.

महत सधस्थं महती बभूविथ महान वेग एजथुर्वेपथुष्टे |
महांस्तेन्द्रो रक्षत्यप्रमादम |
सा नो भूमे प्र रोचय |
हिरण्यस्यैव संदृशि मा नो द्विक्षत कच्चन ||18||

Mahat sadhasthaṁ mahatī babhūvitha mahān vega ejaturvepathuṣṭe |
Mahāmstendro rakṣatyapramādam |
Sā no bhūme pra rocaya |
Hiraṇyasyaiva saṁdṛśi mā no dvikṣata kaccana ||18||

O Mother earth | You give us the place to live. Your speed is tremendous, with which you move in the sky while making lots of vibrations. Indra protects you with great care. Your diving glow is like a gold. Please make us lustrous like you. Let us be free of envy toward each other. Let us be dear to all.

Figure 8: The Atharvaveda. The 63rd verse on Earth about its vastness and magnanimity

Similarly, the 63rd verse of the Atharva Veda (12.1) (Anonymous, 2022m) reverberates the hymns to The Earth, as shown below

"May those born of thee, O Earth, be, for our welfare, free from sickness and waste. Wakeful through a long life, we shall become bearers of tribute to thee."

The Vedas are a collection of the world's most ancient sacred texts, and two of the themes of the Vedas are the love of ecology and the love of Mother Earth. In the Atharva Veda, this ecological theme is clear when it hymns

"Mother Bhumi (Mother Earth),
may whatever I dig from you grow back again quickly,
and may we not injure you by our labour."

There are hymns to Mother Earth in the Bhumi Sukta also, which states

"Earth,
in which the seas, the rivers and many glasses of water lie,
from which arise foods and fields of grain,
abode to all that breathes and moves,
may She confer on us Her finest yield "

(Atharva Veda XII 1:3).

Respect for Mother Earth is deep within our consciousness. We can't deny our love of plants, flowers, gardens, trees, and wildlife. We must address why we are so much in love with nature and yet have not given our Mother what She deserves in our care for Creation? The Vedas are thousands of years old. The Vedic sages [rishis and rishikas (female sages)] were far-sighted in comprehending the role of the Mother Earth (Bhumi Devi) in those ancient days. Their words may sound like the present-day scientific discussion on soils and natural resource management programmes. Sample below:

1. *Do not cut trees because they remove pollution (Rig Veda 6:48:17),*
2. *Do not disturb the sky and do not pollute the atmosphere (Yajur Veda 5:43),*
3. *Don't destroy forests with tigers and don't make forests devoid of tigers.*
4. *Forests can't be saved without tigers and tigers can't live without forests because forests protect tigers and tigers protect forests (Virat Parrva 5:45-46),*
5. *One should protect the habitation (Rig Veda Samhita VI: 71:3).*

Rituals were developed to honour and protect Mother Earth. Parts of the pujas observed the earth items like air, earth, ether, water, and fire. Certain plants and trees were sacred, and groves of trees were preserved. In the Bhumi puja, the priests asked permission from Bhumi to build in a specific place at an auspicious time. This was necessary to accomplish any endeavour towards Mother Earth in this

particular location. The highest good was connected with the cosmic and natural order. This is found in various passages of the Vedas. There is a unity in creation where all human beings are connected and interdependent.

Ayur Vedic medicine is an ancient and modern healing system that shows the connection of all creation. The philosophy behind this kind of medicine is found in the Vedas. Eating the right kind of food and using natural herbs and plants prevent many diseases and help maintain good health (Anonymous, 2022m).

3.2.3 The Bhagvad Gita and Earth

There is mention of mother earth as an oblique reference in terms of soils in the Bhagvad Gita. A few points are worth studying to understand the relationship between God, Earth and soil, and the life of human beings.

Nature is composed of different elements created by God. All the parts of the system naturally draw from and give back to the whole. The sun lends stability to the earth and provides the heat and light necessary for the existence of life. Earth creates food from its soil for us and provides essential nutrients stored in soils to supply them to plants and animals. The movement of air helps transmitting the sound energy as an important force in our body for our survival. God created humans as an integral part of the entire system in the universe. The air that we breathe, the Earth that we walk upon, the water that we drink, and the light that illuminates our day are all gifts of creation to us. While we partake of these gifts to sustain our lives, we also have our duties toward the integral system. Shree Krishna says that we are obligated to participate with the creative force of nature by performing our prescribed duties in the service of God. That is the yagna[15] the Lord expects from us.

The hand is an integral part of the body. It receives nourishment such as blood, oxygen, and nutrients enabling the proper functioning of our body and soul. The hand is a part of our body as a living system and should not be considered as a burden. It is in the performance of its yagna toward the body that the self-interest of the hand is also fulfilled. Similarly, individual souls are tiny parts of the Supreme Soul, and all have their role to play in the grand scheme of things. The Gita suggests the importance of yagna for prosperity [Figure 9; Verse 10 in Chapter 3]. The essence

[15]Yagna: According to the Bhagavad Gita, yagna refers to fire sacrifice and includes all the prescribed actions laid down in the scriptures, when they are done as an offering to the Supreme.

of this shloka is

Brahma has created the universe with the spirit of sacrifice.

Brahma, the Creator, said unto mankind,

"You shall grow and prosper.

Yagna (sacrifice) will bring you all that you wish.

सहयज्ञा: प्रजा: सृष्ट्वा पुरोवाच प्रजापतिः |
अनेन प्रसविष्यध्वमेष वोऽस्त्विष्टकामधुक् ||10||

Saha-yajñāḥ prajāḥ sṛṣṭvā purovāca prajāpatiḥ|
Anena prasaviṣyadhvam eṣa vo 'stv iṣṭa-kāmadhuk||10||

Figure 9: The Bhagavad Gita: Chapter 3, Verse 10 (saha- along with; yajñāḥ—sacrifices; prajāḥ—humankind; sṛiṣhṭvā—created; purā—in beginning; uvācha—said; prajā-patiḥ— Brahma; arena—by this; prasaviṣhyadhvam—increase prosperity; eṣhaḥ—these; vaḥ—your; astu—shall be; iṣhṭa-kāma-dhuk—bestower of all wishes) (Source: Anonymous 2022y https://thegita.net/chapter-3/)

3.2.4 Ancient India and Soils

In ancient India, agriculture was the primary source of livelihood. Farmers were aware of the nature of soils and their influence on plant performance in terms of economic returns. From 2500 BCE to 600 CE vast knowledge was acquired by the farmers and this knowledge was passed on to the generations for their benefit. Although, much of this valuable information was lost due to the absence of documentation, many were kept alive through pastoral songs, maxims, and various proverbs in local vernacular to guide farmers through generations. A few are mentioned in the following paragraphs.

Fertility-based Indian soil classification

Soils were classified into two based on their fertility. These are ***urvara*** (Sanskrit, meaning fertile) and ***anurvara*** or ***usara*** (Sanskrit, meaning unfertile or sterile). Urvara ***mrittika*** (Sanskrit, meaning soil) was again classified keeping in mind the crops grown in it such as ***yava*** (Barley: ***Hordeum vulgare***), ***tila*** (Sesame: ***Sesamum indicum***), ***vrihi*** (Rice: ***Oryza sativa***) and ***mandiena*** (Mung: ***Vigna radiata***). The ***anurvara mrittika*** (unfertile or sterile soil) was classified into ***usara*** (sandy ground) and ***maru*** (desert). Soils irrigated by the river were called ***nadimatrika***, and by rains as ***devamatrika***.

Crop suitability-based Indian soil classification

Soils were classified based on the suitability of different types of crops (***Arthashastra***, ca. 3000 BC). Lands with soils receiving a regular flow of river water

on the bank were suitable for pumpkins (***Cucurbita pepo***) and gourds (***Lagenaria siceraria***). Lands prone to frequent flooding were suitable for pepper (***Piper nigrum***), grapes (Vitis sp.), and sugarcane (***Saccharum officinarum***). Lands that were situated near wells were found to be suitable for green vegetables. For fragrant plants (flowers) and medicinal herbs, marginal furrows between rows were suggested.

Soil classification according to climatic variation

According to the nature of the soil and climatic variations lands were classified into i) jangala, ii) anupua and iii) sadharana by Charaka (Raychaudhuri, 1975).

i. Jangala: Dry places with typical plants now called Xerophytes.

ii. Anupua: Marshy/swampy and watery lands with thick forests, trees, and flowers encircled by creepers.

iii. Sadharana: These are lands with ordinary plants (Mesophytes). These lands are covered by creepers, other plants, and trees like vanaspati and vanaspatvas.

Another soil classification by Misra Chakrapani showed arid lands, wetlands (i.e., marshy), and moderate land. All the soils in these lands were distinguished by six tastes through colours, viz.

Soil colour	Taste
Grey	Sweet
Pale white	Sour
Black	Salty
White	Bitter
Red	Pungent
Yellow	Astringent

Besides, soils in those landscapes covered by anthills, pits, and stones are often saline and gravelly, where groundwater strikes at a greater depth. These soils were also considered bad for planting trees. Lands were also classified into a) wetlands used for growing paddy and are named ***sali- bhumi, jala-bhumi,*** and ***sasya-bhumi***, and b) drylands, also called ***adhaka-bhumi, tara-bhumi***, and ***usar bhumi*** (Velayutham et al., 2016). Excellent land was identified by a mild colour like

sapphire or the plumage of a parrot, or is in the colour of conch or the moon or could be as bright as molten gold.

Land classification using a revenue system

Revenue is rated based on soil quality, as evidenced by its capacity to produce. The ***Arthashashtra*** and the ***Sukraniti*** indicated land gradation, according to survey and measurement, to estimate the productivity and expenses per unit of land. Rules used to be stringent regarding producer surplus and rating soils based on productivity. Megasthenes[16] noted that during the Maurya Dynasty, the officers were careful about the measurement and supervision of the alluvial lands for revenue generation. Crop and soil suitability, as parameters for land assessment classification, came into existence during the 16th century. Other factors considered for evaluating land/soil were texture, colour, water availability, the slope of the land, and crop yield. Besides, soils were classified based on the source of water used to grow crops (Bhattacharyya, 2021a).

Sr. No.	Soil	Water source
1.	Barani	Rainfall
2.	Chahi	Wells
3.	Nahri	Canals
4.	Sailabi	River

3.3 Prayers on soils in Hindu literature and scriptures

3.3.1 Generalities

Developments in science, mathematics, civilization, and agriculture were part of the Vedic agriculture and the Vedas has a great contribution for such achievements. The Vedic people were skilled in cultivation and succeeded in agriculture. These people strictly followed all cultures and traditions to relate religious customs with agriculture. Vedic agriculture was performed with a proper understanding of the weather and monsoons (Anonymous 2022l). Sages in those times immensely contributed to Vedic agriculture. The rishis wrote hymns in the Rig Veda and Atharva Veda about the importance of rain and cattle. The Atharva Veda narrated the vidhis (methods, rituals) to increase soil fertility and improve the productivity of the cultivated land. The Vedic people also achieved knowledge of

[16]Megasthenes was an ancient Greek historian, diplomat, and Indian ethnographer and explorer in the Hellenistic period. He visited India sometime during the reign of Chandragupta Maurya.

manuring soils. These people used waste materials like leaves, cow dung, etc. These were collected into a pit for decomposition. This process made the soil more fertile and suitable to produce good crops.

The primary source of the Vedic Aryans' living was farming and animal breeding. They are described as farmers in Rig Veda. The Aryans gave a lot of importance to agriculture (Mishra, 2002). The word ***kshetra khet*** indicates that different types of fields and lands such as agricultural land was in existence. Aryans knew the art of sowing seeds with the help of a plough (***vruk***); the Brahman and Sanhita also described the art of agriculture. The plough (***lagal/sir***) with its front sharp part (***fal***) was pulled and drawn by 6/8/12 bullocks suggesting the heavyweight and enormous size of the plough. The fields were usually rich in producing crops. If otherwise, manures (crop-nourishing agents) were used. The cow-dung (***karish***) was used for this purpose along with the natural waste - products of animals.

Farming seasons were also described. Rice gets ripe in autumn and is sown at the beginning of the rainy season (***varsha***). Mash (***udid/urad***) and ***tila*** (sesamum) are sown during the rain in summer and get ripe in winter. The seeds were sown during winter and get ripe during the months of ***Chaitra***. Problems of insects and other animals and natural calamities like drought were thwarted by chanting mantras. There is a reference to the destruction of a ***Kuru Janapada*** due to insects (***matchi***). Sometimes, the Matchi (***Hateshu Kurushu***) destroy the crops.

Irrigation by different methods such as well was also prevalent in ancient days. The water from the well was drawn out with wheels created from stones. There are mantras and hymns in Rig Veda which depict the importance of agriculture and farming. One of them in Sanskrit advised people to get rid of the bad habit of gambling and instead learn the art of farming (Figure 10).

"Akshaya Divyaha Krushimit Krushaswaha"

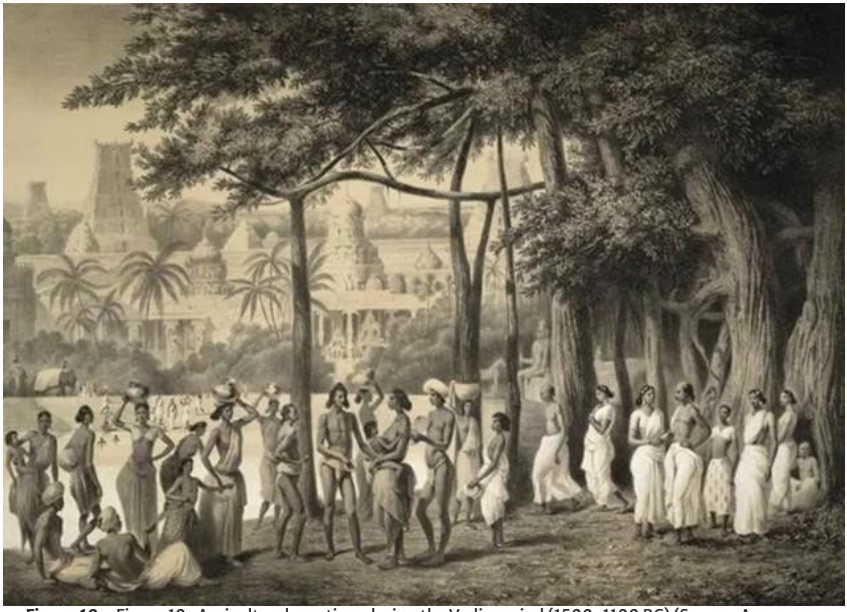


Figure 10: Figure 10. Agricultural practices during the Vedic period (1500–1100 BC) (Source: Anonymous, 2022)

3.3.2 Practices by Hindus to reflect their attachment to animate objects

Practices by Hindus to reflect their attachment towards animate objects are old. The cow symbolises all other creatures for a Hindu. The cow symbolises the Earth, the nourisher, the ever-giving, and an undemanding provider. She is believed to be very dear to Lord Krishna and so Krishna devotees consider the cow as the holy animal. It is the most worshipped animal in India; the bull is also worshipped by farmers. The ***Varah Purana***[17] mentions that one who plants one ***peepal*** (***Ficus religiosa***), one ***neem*** (***Azadirachta indica***), ten flowering plants or creepers, and two pomegranates (***Punica granatum***), two oranges and five mangos (***Mangifera indica***), does not go to hell.

[17] The Varaha Purana (Sanskrit: Varāha Purāṇa): It is a Sanskrit literature on Hinduism. It belongs to the Vaishnavism praising Narayana (Vishnu).

3.3.3 Practices by Hindus to reflect their attachment to inanimate objects

Hindus have special reverence towards forests, flowering trees, and groves which are considered sacred. Just as the animals and birds are associated with *gods goddesses*, different trees and plants were also associated with the worship of deities such as ***Indra, Varuna***, and ***Agni***. Fire sacrifices (***yagna***) are performed by chanting Vedic mantras. These Vedic rites of fire (offerings to God) are observed during practices like Hindu weddings and burial ceremonies.

All plants and flowers have medicinal value in the Hindu system of medicine (***Ayurveda***). It is believed to be brought by ***Dhanvantari*** (the divine medicine man) during ***Samudramathana*** (churning of oceans). Tulsi (***Ocimum sanctum***) is considered a venerated plant, and Hindus worship it every morning and evening. The presence of the ***tulsi*** plant symbolizes the religious bent of a Hindu family. Generally, ***tulsi*** is planted in a specially built structure, with images of deities installed on all four sides to open a small earthen oil lamp.

3.3.4 Other prayers related to earth and soils

A few selected prayers related to mother earth/soil are mentioned in the following paragraphs.

Prayers from Rig Veda to dawn) (Mandala I, Hymn 113) (Griffith, 1896)

- Fair-formed of different hues and yet one-minded, Night and Dawn clash not, neither to their tarry.
- Even that may Mitra, Varuna vouchsafe us, and Adita and Sindhu, earth and heaven.
  (To fire) (Mandala II, Hymn 4) (Max Muller,1908)
- He who shines on the forests as if he were thirsty, who resounded like water on its path, like (the rattle of the wheels) of a chariot-he whose path is black, the hot, the joyous one has shone, laughing like the sky with its clouds.

Prayers from Atharva Veda (to Goddess Earth) (Book XII, Verses 1-27) (MaxMuller,1908)

- Truth, greatness, universal, strength, order (rita), consecration, creative fervour (tapas). Spiritual exaltation (brahma), the sacrifice, supports the earth. May this earth, the mistress of that which was and shall be, prepare

for us a broad domain!

- The earth that has heights, and slopes, and great plains, that supports the plants of manifold virtue, free from the pressure that comes from the midst of men, she shall spread out for us, and fit herself for us!

- The earth upon which the sea, and the rivers and the waters, upon which food and the tribes of men have arisen, upon which this breathing, moving life exists, shall afford us a precedence in drinking!

- The earth whose are the four regions of space, upon which food and the tribes of men have arisen, which supports the manifold breathing, moving things, shall afford us cattle and other possessions also!

- The earth upon which of old the first men unfolded themselves, upon which the Gods overcame the Asuras, shall procure for us (all) kinds of cattle, horses, and fowls, good fortune and glory!

- The earth that supports all furnishes wealth, the foundation, the golden-breasted resting-place of all living creatures, she that supports Agni Vaisvanara (the fire), and mates with Indra, the bull, shall furnish us with property!

- The broad earth, which the sleepless Gods ever attentively guard, shall milk for us precious honey, and, moreover, besprinkle us with glory!

- That earth which formerly was water upon the ocean (of space), which the wise (seers) found out by their skilful devices; whose heart is in the highest heaven, immortal, surrounded by truth, shall bestow upon us brilliancy and strength, (and place us) in supreme sovereignty!

- The earth upon which the attendant waters jointly flow by day and night unceasingly, shall pour out milk for us in rich streams, and, moreover, besprinkle us with glory!

- The snowy mountain heights, and thy forests, O earth, shall be kind to us! The brown, the black, the red, the multi-coloured, the firm earth (soil) that is protected by Indra, I have settled upon, not suppressed, not slain, not wounded.

- Into thy middle set us, O earth, and into thy navel, into the nourishing strength that has grown up from thy body; purify thyself for us! The earth is the mother, and I the son of the earth; Parjanya is the father; He, too, shall save us!

- The earth, clothed in Agni, with dark knees, shall make me brilliant and alert!
- Upon the earth men give to the Gods the sacrifice, the prepared oblation; upon the earth mortal men live pleasantly by food. May this earth give us breath and life, and may she cause me to reach old age!
- Rock, stone, dust is this earth; this earth is supported, held together. To this golden-breasted earth, I have rendered obeisance.
- The earth, upon whom the forest-sprung trees ever stand firm, the all-nourishing, compact earth, do we invoke.

Prayers from the Chandogya Upanishad (Vi Prapathaka) (First Khanda) (MaxMuller,1908)

The father (Uddalaka, the son of Aruna) and son (Svetaketu) conversation

Son: What is the instruction, Sir?

Father: My dear, as by one clod of clay, all that is made of clay is known, the difference being only a name, arising from speech, but the truth being that all is clay; And as, my dear, by one nugget of gold all that is made of gold is known, the difference being only a name, arising from speech, but the truth being that is gold; and as, my dear, by one pair of nail-scissors all that is made of iron (karshnayasam), is known, the difference being only a name, arising from speech, but the truth being that all is iron.....!

4. Perceived benefits of soils

At local, regional, and international levels, the benefits of soils are increasingly appreciated.

Soil's benefits are acclaimed globally as evidenced by celebrating World Soil Day over the years (Table 2) (Bhattacharyya 2022; 2021a, b). This appraisal of the importance of soil science is important since it transcends human life, expertise, and experiences by many generations, even centuries. A few examples of soils and their benefits are summarized in the following paragraphs.

Table 2: Themes of World Soil Day

Year	Theme
2015	Healthy Soils for a Healthy Life
2016	Soils & Pulses: Symbiosis for Life
2017	Caring for the Soil starts from the ground

2018	Be the Solution to Soil Pollution
2019	Stop Soil Erosion, Save our Future
2020	Keep soil alive, protect soil biodiversity
2021	Halt soil salinization and boost soil productivity
2022	Soils: Where food begins

Soil is in the interface between the atmosphere, including the biosphere, hydrosphere, and pedosphere (Figure 11). Soil is the ultimate result of the interaction of various factors such as climate (atmosphere, hydrosphere), relief (biosphere), organisms (biosphere), parent material (pedosphere), and time. Soils formed from the combined influence of these factors help provide various perceived benefits to a human being.

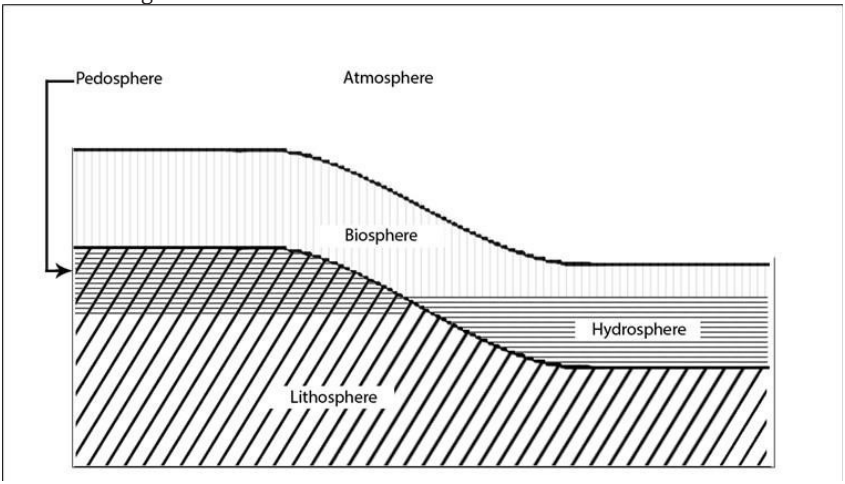


Figure 11: Soil as an interface between different spheres of the environment

4.1 Soil and environment

A range of services essential to our health and well-being of society, in general, and the environment, in particular, are provided by soils. Therefore, soils play an indispensable role in our natural ecological cycles, namely carbon, nitrogen, oxygen, water, and nutrient, to contribute to the overall ecosystem services. Soils are the natural habitat of biological systems to provide heat, nutrients, and water

for their sustenance. These systems, together with other natural resources, create ecosystems. Soils play many ecological roles, such as:

a. providing habitat for the growth of living organisms

b. recycling organic wastes, water, and nutrients (air quality and composition)

c. maintaining atmospheric equilibrium (temperature regulation)

d. offering a system for water supply and purification (filtering)

e. source of raw materials,

f. the link between physical and cultural heritage, and

g. a base for infrastructure.

To comprehend soil and its role in the environment, both internal (pedo-environment) and external (above-ground) functions need to be understood. The environment in a broader sense, includes ecosystems. Soil is at the interface of this larger environment (Figure 11). A dynamic complex of plant, animal, and microorganism communities form an ecosystem which include the non-living environment and all these components interact among themselves. Since soils support flora and fauna on which humans and animals depend, the soil is part of the larger environment. Soil bridges the link between the air, water, rocks, and organisms. And thus, soil controls different functions in the natural world to provide various ecosystem services. The role of soil in the ecosystem is manifold. Soil has a role to play in every walk of human life as detailed in the subsequent paragraphs.

4.1.1 Soil habitat: Food and biomass production

Seeds grow in the environment soils provide. They provide nutrients, water, and another necessary environment that nurtures plants for survival which in turn cohabit with other organisms to create ecosystems. Soils are part of these ecosystems. These plants provide valuable habitats and form the primary sources of food for animals, microorganisms, and humans. Besides, decomposed organic matter from plants and trees forms biomass in soils.

4.2 Interaction between soil and environment

4.2.1 Quality of air

Soil, if covered appropriately by vegetation (plants and trees), can protect against erosion. This can restrict wind erosion to control the purity of atmospheric air, which in the desert area is always contaminated with impounded air particles causing a major health problem. These particles contain various microorganisms which can cause infection and diseases.

4.2.2 Temperature regulation and soil

Soil temperature plays an important role in chemical, biochemical, and biological interactions in the soil environment. Soil temperature, in turn, influences seed germination, the proliferation of microbes, making nutrients available to plants and microbes, and the decomposition of organic matter in the soil. In soils of the cold region, cool temperature retards the pace of biochemical reactions ensuring more organic carbon storage. Tropical soils, in general, are poor in organic carbon as they cannot store more organic matter due to the high atmospheric temperature, so typical of tropical climates.

4.3 Soil utility

4.3.1 Carbon and nutrient cycling

Soils contain carbon both in organic and inorganic forms. While organic carbon is a boon for farmers, inorganic carbon is mostly a bane . Natural processes are all cyclical and so are the processes through which all nutrients and carbon in the soil are cycled. The carbon cycle is more complex and involves carbon stored in fossils, soils, oceans, and rocks on a global level.

The organic carbon compounds and their balance are controlled by physical, biological, and chemical processes in the soils. Organic compounds, after decomposition, form CO_2,which are either stored in soils or are released into the atmosphere. The same process occurs with nitrogen, phosphorus, and all other materials.

4.3.2 Soil as filter for water

Soil is a great sink; it is a great source as well. The water we consume and use for other purposes is always filtered through the soil. Not only so, but soils also absorb water, retain it and make it available for flora and fauna. Water cannot be stored without soil and soil particles. Soil acts as a sponge, soaking water into the ground during rains to provide water for all living beings. This water can be used

by plants, microbes, and other living things; water also fills the underground aquifers and lakes and flows into streams before eventually making it to the ocean. If external water contains harmful materials, the soil acts as a filter. Soil, thus, makes the water potable for us. Soil filters water as it reaches the land surface into the groundwater. This process occurs through physical, chemical, and biological processes. For example, septic systems (for sanitation) rely on these processes to protect groundwater quality and maintain the quality of the water supplied to us for drinking. If soils are not protected then these materials can pollute water, and these pollutants might wash away into streams and oceans affecting the overall ecological balance.

4.3.3 Soil as a gene pool and biological habitat

It is believed that more species exist below the soil surface than above it. Soil is the habitat of organisms, including microbes and higher animals (Bhattacharyya 2021a). These are highly beneficial to soil physical and chemical processes that influence soil fertility and productivity. Soils have vertebrates (mice, mites, and prairie dogs). These burrowing animals redistribute soil materials from deeper layers to reach the surface. Organic matter is also physically shredded into smaller particles to make decomposition easier. Macroorganisms in soil include earthworms, termites, and ants. These animals fill the soil through their burrowing action. Their faeces serve as rich sources of soil materials. Several species of fungi in the soil are important in decomposing organic materials to form humus and thus help form soil aggregates. Other important microbes include actinomycetes, algae, bacteria, nematodes, and protozoa. Actinomycetes give soil its characteristic earthy aroma when it rains. Soil has a diverse system of biological characteristics often termed soil biodiversity. This system is beneficial to plant growth, including crop production. With increased diversity, the decomposition of organic matter and the release of more nutrients are made possible. Table 3 shows different soil organisms and their role (Bhattacharyya 2021a, b).

Table 3: Organisms and their role in soils
(Sources: Bhattacharyya and Pal, 2015; Angelina and Nivvedha, 2021; Alexander, 1961; Yuvaraj and Ramasam, 2020; Foissner, 2014; Thomas and Culliney, 2013)

Organisms	Roles		
	General Role	Roles in decomposition	Roles in releasing plant nutrients/ diseases
Algae, Bacteria	Help in photosynthesis	Algae: photoautotrophic nutrition to generate organic matter from inorganic substances; contribute to soil structure and erosion control; soil genesis, stabilization of soils, soil friability,	Algae: Capacity to utilze N and helps crop production; enrich soil N
		Bacteria: Catalyse energy yielding reactions; recycling palnt residues in to useful nutrients; involved in N cycle (nitrification, denitrification), C, P, S cycles	Bacteria: Provides nitrate and sulphide for plants: N fixation in terrestrial plants;

Actinomycetes, Bacteria, Fungi	Decomposition of organic matter	Actinomycetes: development of a broad range of growth-stimulating compounds and metabolites such as antibiotics, to resist biological and abiotic stress conditions for host plants; plant-growth-stimulating activities, such as the production of IAA (Indole 3 Acetic Acid), siderophore, solubilization of phosphate, nitrogen fixation, and the refurbishment of the soil system's ecological balance Few strains can synthesize toxic metabolites; decomposition of resistant components of pant/ animal tissues; Formation of humas.	Actinomycetes: Caues of soil-borne diseases such as potato scab
		Fungi: Formation of humus in soils; influence in different physiological processes as well as mineral and water uptake, chemical change, stomatal movement, and biosynthesis of compounds termed bio stimulants, auxins, lignan, and ethylene to enhance the flexibility of plants to ascertain and cope environmental stresses like drought, salinity, heat, cold, and significant metals	Fungi: Saprophytic species invade plant tissues causing diseases; also used as edible food items as mushroom

Protozoa, Nematodes, Arthropods	Release plant-available nutrients	Protozoa: Regulate the size of bacterial population; saprozoic types participate in decomposition of plant residues; Participates in the decomposer cycle and plant growth, and are valuable bioindicators for natural and anthropogenic influences	Protozoa: Releases nutrients from decomposed bacterial biomass
		Nematodes: decomposition of organic matters in soil and are beneficial to plants.	Nematodes: Few nematodes live in association with specific bacteria and can infect insect pests; it releases bacteria that multiplies in host insect and kill them
		Arthropods: Plant litter transformers or ecosystem engineers; burrowing by arthropods improves soil porosity to provide adequate aeration and water-holding capacity below ground, facilitate root penetration, and prevent surface crusting and erosion of topsoil; helps in pedogenesis; pedoturbation.	Arthropods: Microbial mineralization of nutrients may be stimulated by arthropod; regulate the availability of nutrients to plants

Earthworms, Arthropods	Shred residues Earthworms, improve soil structure, make burrows in soils, and redistribute the nutrients	Earthworms: significantly modify the physical, chemical and biological properties of the soil profile;	Earthworms: Incorporate organic materials into the soil; unlock the nutrients held within dead organisms and plant matter; maintain soil fertility and health
Bacteria (in nodules of legumes)	Fixation of atmospheric nitrogen	N-fixing bacteria: Conversion of stable nitrogen gas in the atmosphere to a biologically useful form; Nitrogenase enzyme reduces dinitrogen to ammonia.	N-fixing bacteria: Rhizobium as N-fixing bacteria can be pathogenic as well as non-pathogenic; N added in soils as an important plant nutrient.

Since soil acts as a shelter for many organisms, it can be considered a genetic reserve or gene pool, ensuring the conditions for biodiversity in the edaphic environment. Estimates of the number of species of some groups include bacteria (30000 nos.), fungi (1500000 nos.), algae (60000), protozoa (10000), nematodes (500000), and earthworms (3000). One gram of soil may contain 109 bacteria, 107 actinomycetes, 106 fungi, 104 algae, and 105 protozoa (Figures 12,13). Bacteria are an essential part of the soil micro-flora due to their abundance and species diversity (at 4000 to 7000 genomes per gram of soil).

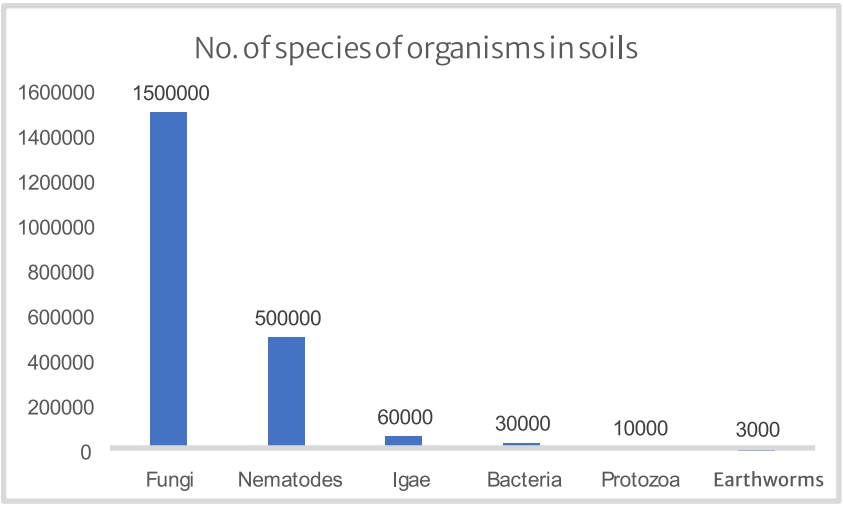


Figure 12: Different species of organisms in each gram of the soil.

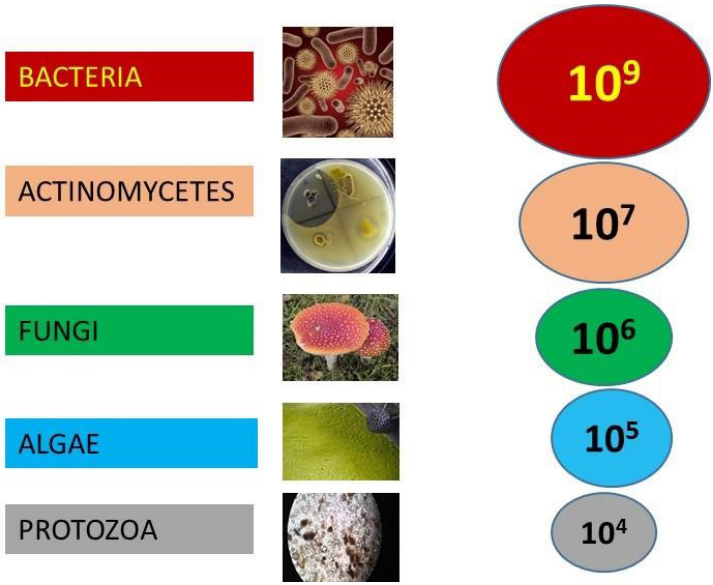


Figure 13: Figures 13. Number of microbes in one gram of soil: a comparison

Soil as a gene pool was first used by D. Waksman (Nobel Laureate in 1952) to isolate an antibiotic compound from the actinomycetes. Antibiotic groups extracted from the soil are aminoglycosides, glycopeptides, tetracycline, and cephalosporin. Nearly 78% of antibacterial agents approved between 1983 and 1994 originated in soils. The genetically-modified crops are being developed with the help of microbes from the soil.

4.3.4 Raw materials and soils

Soil is a source of several raw materials for industry. It supplies ores for iron, which is used for the steel industry. Aluminium ore as bauxite is excavated from soils. Several minerals [like zinc (Zn), and magnesium (Mn)] are mined from the soil. Many pharmaceutical industries depend mainly on soil-mined minerals. Products of our daily use like toothpaste, talcum powder, creams, and many such items, require clay minerals (obtained from soils) as fillers. The construction of a building involves wood, bricks, and metals, which are obtained from soil. Soil is located between the lithosphere, atmosphere, and biosphere. It, thus, becomes one of the essential components of the environment, performing numerous functions in terrestrial ecosystems, as shown in Figure 14.

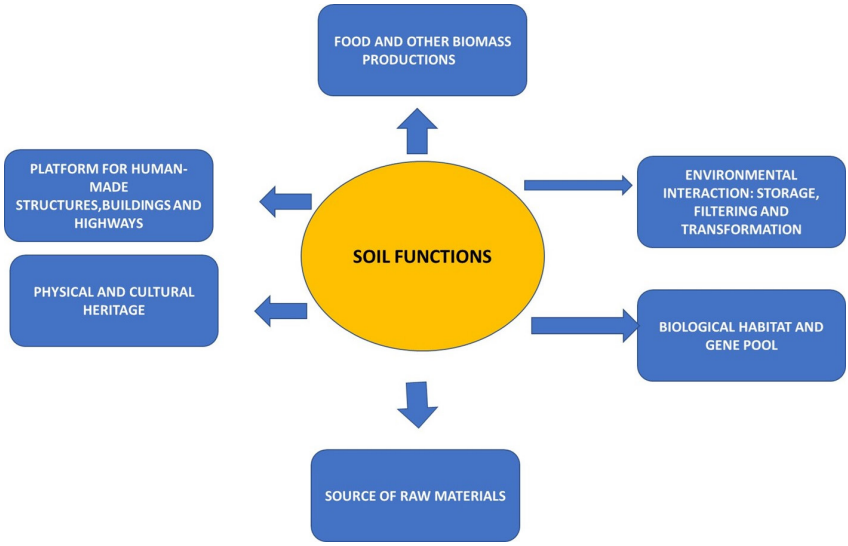


Figure 14: Figure 14. Schematic presentation of soil functions

(Source: Bhattacharyya and Pal, 2015)

4.3.5 Heritage, archaeology, and soils

4.3.5.1 Physical and cultural heritage: Link with the soil

Soil acts as a physical and cultural heritage of the natural and cultural history of human society because it reflects the evolution of natural conditions in an agricultural region and some aspects of human evolution. Thus, based on the fossils discovered in the soils, the climate and vegetation characteristics in a certain period can be reconstructed. Soil is a good indicator of environmental quality and evolution since it can permanently adapt to natural or artificial changes and memorise past events.

Many archaeological materials such as coal, ash, pottery, tools, bones, and remains of shells can provide important information on the paleontological nature of the past including the soil age. The soil has been able to relate to the evidence of human civilization. Soil has a beautiful memory to keep the past information to trace the events of earlier civilizations. Soil protects all the evidence of the past, which are extremely important to understand the evolution of life on Earth. Regarding cultural function, the soil is a natural geological and archaeological heritage to look into the culture of human civilization (Figure 15).

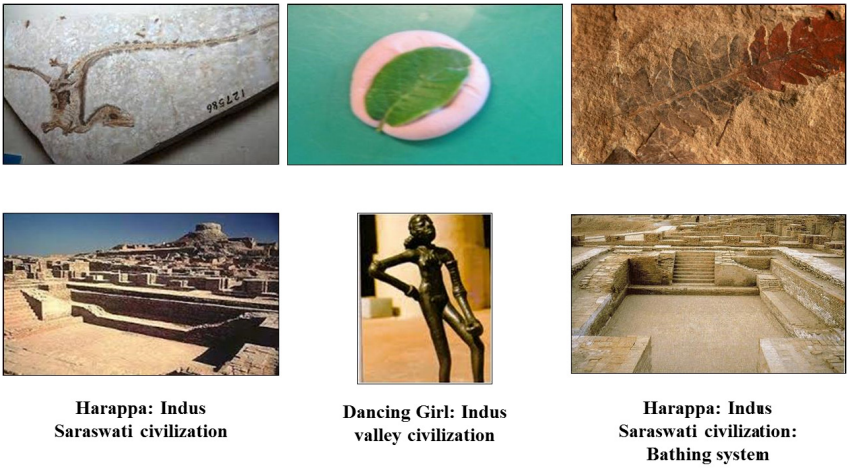


Figure 15: Soil has memory and acts as a storehouse of past events

4.3.5.2 Remote sensing in archaeology and agro-tourism

Remote sensing is being applied in archaeology and is gaining momentum in conserving various heritage sites at the global level. To stitch the story of the past, the use of modern technology in this particular field has a huge potential to facilitate the tourism industry. The fusion of past and present in the form of space archaeology might pave the way for tourism and agro-tourism to help rural people. Archaeologists uncover the past by digging through layers of civilization. Gradually, sand or layers of soil and dirt can cover a lost city. Using remote sensing techniques, it is possible to study such difficult sites using satellite data. Using such modern techniques to visit the past and build its stories comes under the purview of space archaeology. Satellite remote sensing is now a common aspect of investigation, and prediction of environmental change, and scenarios through the development of GIS-based models. A few other advantages include (a) estimating archaeological parameters, including surface and/or subsurface properties without coming in direct contact with the object of study, (b) economic, since it reduces costs of in-situ investigations, and (c) easy monitoring and using temporal-spatial data analysis (Tapete 2018). For various archaeological purposes, India can be divided into five regions such as i) the Indus basin with its affinity with Persia and Central Asia, ii) the Indo-Gangetic Plains (Bhattacharyya et al., 2004) with its link to Central Asia, iii) barren hills and deserts acting as a barrier iv) running across the whole country from the north-west corner of the Bay of Bengal on the east almost to the Indian Ocean on the west, and, v) the peninsular India (Anonymous 2020 a).

Space archaeology is a multi-disciplinary subject involving the expertise of geologists, soil scientists, chemists, remote sensing experts, and a host of archaeologists (Ambekar et al., 2014). In fact, archaeologists have started using satellites proving their effectiveness in site detection.

Sites need to be detected rapidly and over large areas as India's landscapes are varied and massive. Space archaeology, with the advent of GIS and other software techniques, can be made open to an online platform to launch citizen archaeology for easy access to historical sites and benchmark spots for informing the monitoring agencies about (a) the existence of new sites not yet mapped and listed, (b) extent of damage caused for future conservation, and (c) educating locals to understand the importance of these historical sites built many years ago and cannot be rebuilt (Figure 16).

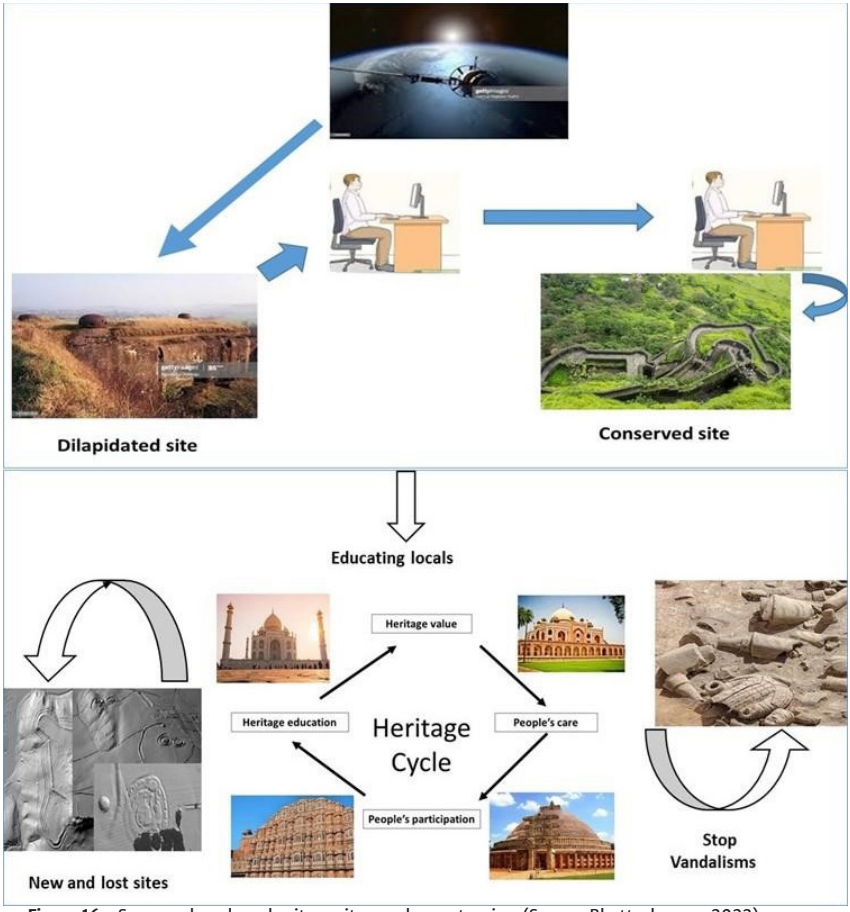


Figure 16: Space archaeology, heritage sites, and agro-tourism (Source: Bhattacharyya, 2022)

4.3.6 Role of soil in making infrastructure: Non-agricultural use of soils

Soil acts as a support for houses, individual buildings, communication ways (roads, highways, and airports), sports fields, and storage of household and industrial wastes. It gives an environment for pipeline installation and underground cables. The soil resulting from the excavation of the foundation is also used to cover dumps of wastes from metallurgical complexes or to cover the garbage near cities as a solution for protection against environmental pollution (Figure 17).

Figure 17: Use of soil in building infrastructures: roads, buildings, airports, sports fields, and sink for waste materials (Bhattacharyya 2021a)

4.3.7 Use of soils in petrographic, mineralogical, and geochemical studies: Archaeological evidence

Natural resource managers, in addition, to helping to find out missing archaeological evidence, may help in finding the source of various types of historical evidence through chemical, geochemical and mineralogical studies. Soil scientists may help experts of other branches working on non-agricultural aspects of soil research. Such studies may form a future collaboration with soil scientists and archaeologists to find the historical truth. There was discussion about the provenance of cannon balls in Goa on whether it was from India or brought by the Portuguese from elsewhere. Archaeological, petrographic, mineralogical, and geochemical studies were carried out on samples of millstones and the quarried site at Dharavi (Uttan) (Figure 18). In addition, the sample was also collected from cannonball found at Arsenal (Old Goa) to find out whether stone from Dharavi (Uttan) was used. The analytical results of basalts present nearby at Bassein (Dharavi, Uttan) did not match the composition of the cannon balls. It seems, therefore, that although stones from Dharavi (Uttan) were quarried for the decoration of churches of Goa by the Portuguese on a larger scale, the same was not suitable for cannon balls due to their fragile nature and hence not used (Ambekar et al., 2015).

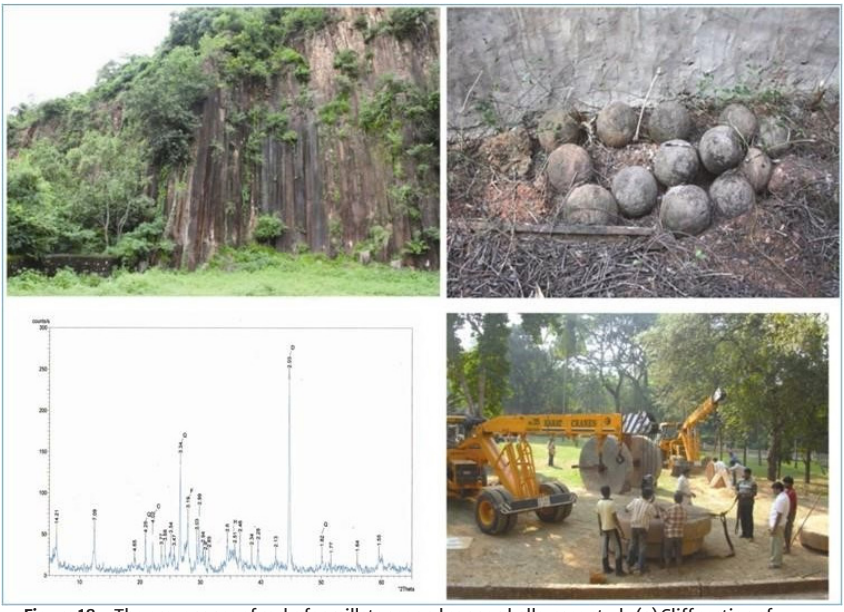


Figure 18: The provenance of rocks for millstones and cannon balls: case study (a) Cliff section of the quarried site at Dharavi (Uttan); (b). Cannonballs at Arsenal, Old Goa; (c) X-ray diffractogram of) powdered cannon ball sample (C, Calcite; F, Feldspars; H, Hematite; Q, Quartz; O, Opal CT; and (d) vanished site by salvage archaeology (Source: Ambekar et al., 2015)

4.4 Soil as a medium for plant growth

Soils are the stomach of plants, while plants' leaves are their kitchen. Early humans relied on natural fruits, vegetables, and animals that the soil produced directly or indirectly. Our ancestors understood that soils could be used as the best medium for plant growth since soils can supply adequate moisture and nutrients and hold the plants for their growth. We developed ways to cultivate and manage soils which include fertilization, irrigation, and plant protection measures. Life thrives in the biosphere, the zone at the interface of the earth's crust and the atmosphere. Here, the sun provides radiant energy, which green plants capture and transform into sugars and other valuable chemicals through photosynthesis (Figure19).

Figure 19: Role of soil as a medium for plant growth

Soils provide nutrients, water, oxygen, and physical support to plants (everything plants need except the energy from the sun and CO_2 from the air). As organisms in the soil decompose dead plants and animals, CO_2 is returned to the air to complete the cycle. A comparison of atmospheric and soil CO_2 is shown in Figure 20.

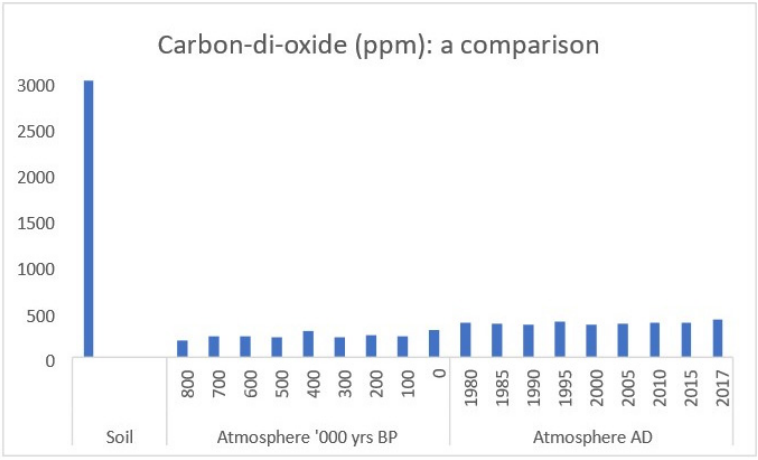


Figure 20: Carbon-di-oxide: soil and atmosphere(Reconstructed from data in http://www.gov/newsfeatures/understanding-climate/)(BP: Before Present; AD: anno domini)

Soil is the most complex element of the environment; it provides a vital link that connects the abiotic (inorganic), biotic (organic), and anthropogenic (human) components. It is an essential component of all-natural and anthropogenic ecosystems. Because of its process of self-purification and neutralization of organic pollutants, the soil favours the support of a certain balance in the environment. Rational use and soil protection can determine our future. All of us must see that this precious natural resource is saved so that future generations can secure their needs, such as food, fodder, and fuel. This way, we can respect and protect the right to the survival of our posterity.

5. Medicinal benefits of soils

Soils influence (i) food availability and its quality (food and nutritional security), (ii) human contact with various chemicals, and (iii) human contact with different types of soil-borne pathogens. The link between soils and human health is well-known, although the scientific study is recent (Singh, 2009; Brevik and Sauer, 2015). Different experts contributed to this area of study: soil scientists, agronomists, geologists, biologists, anthropologists, and medicinal experts. It has been stated that the medical profession has ignored soils in their efforts to improve human health and that soils should be the foundation (Shukla and Pakhare, 2015).

5.1 Soils and human health

Although soils produce most of the foodstuffs yet many of us are not aware of the role of soils in human health. The nutrients soils provide to plants and animals and their consumption by humans make a chain and thus, soils directly/indirectly influence the life of people. Influencing human health may have both positive and negative effects (Brevik, 2013).

5.1.1 Soils and human health: Ancient history

Although human health is discussed and various experts suggested different treatments to maintain the health of a person, very few thought it important to see how soil is involved in maintaining the health of that person. Many years back, a vital link between soil and human health was recognized (Figure 21).

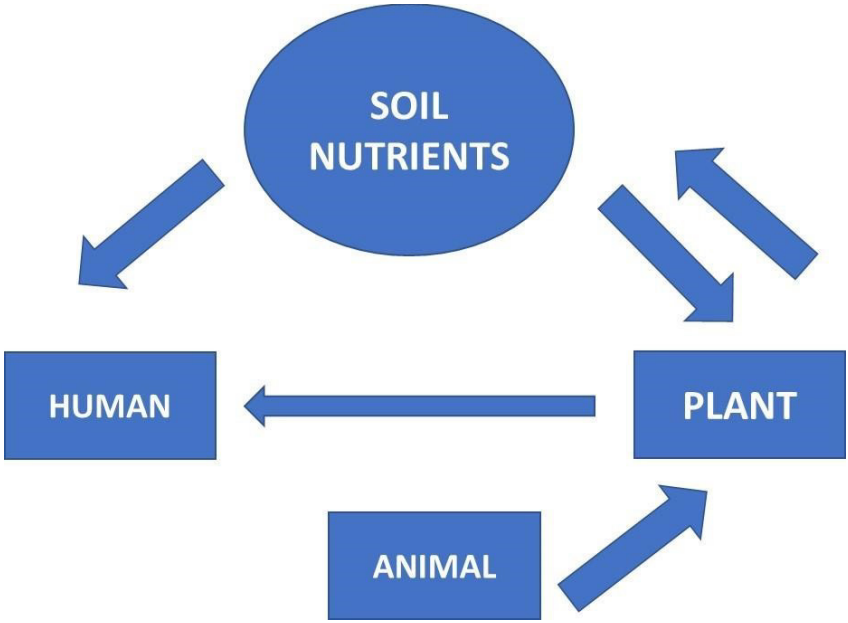


Figure 21: Soil-animal-human continuum and maintenance of their health.

The Bible depicts that fertile soil was essential for the better health of people. In 400 BCE, Hippocrates, a Greek philosopher, suggested that medical evaluation should include properties of local land/soil for an exact diagnosis. Geophagia, a Greek word, indicates the intentional consumption of soil. A similar reference is found in the Mahabharat (3200 BCE), where Lord Krishna in his childhood, was found eating soil. At least 2000 years ago, specially minted clay coins (Terra sigillata)[18] used to be sold in Greek markets. Geophagia, common among children, pregnant women, and adolescent girls, may have bad/sound effects on health. During the famine, clay consumption (soil) is reported in China, Sudan, North Carolina, and Zimbabwe. Speculation about the decline of the Mesopotamian civilizations and the collapse of the Indus Valley Civilization in 2000 BCE was related to the soil-related problems. One of the reasons for the Maya Empires' (~600 CE) decline is related to soil

[18]The oldest use for the term Terra sigillata was for a medicinal clay from the island of Lemnos. The latter was called "sealed" because cakes of it were pressed together and stamped with the head of Artemis. Later, it bore the seal of the Ottoman sultan. This soil's particular mineral content was such that, in the Renaissance, it was seen as a proof against poisoning, as well as a general cure for any bodily impurities, and it was highly prised as a medicine and medicinal component (https://en.wikipedia.org/wiki/Terra_sigillata#Medicinal_earth)

problems and malnutrition (Shukla and Pakhare, 2015). In 1700 CE, there was a paper by de Crevecoeur (Letter from an American Farmer) where soil and plant relations were discussed. In the 20th century, Mc Carrison (1921) stated that soil fertility and vitamin content, and its bacterial population are related to human health.

Allergies and immunity-related problems are again related to exposure to soil microbes (Rook, 2010). Nearly 78 per cent of antibacterial agents applied between 1983 and 1994 are from soils (Pepper et al., 2009). Besides, almost 40 per cent of all prescribed drugs have their origin in soil.

5.2 Health and nutrient imbalances in soil

Fourteen essential elements for plant growth come from the soil (Havlin et al., 2005). Many of these elements, such as calcium (Ca), iron (Fe), potassium (K), phosphorus (P), and others, are also essential for human health (Leitzmann, 2009; Combs, 2005; Klasing et al., 2005). Essential soil elements that end up in the human diet are primarily supplied through food from either plant (that took the elements up from the soil during growth) or animal products (after the animal obtained those essential elements from plants through soils) (Klasinget al., 2005; Abrahams, 2002; Voisin, 1959). Out of the 29 elements considered essential for human life, 13 are essential plant nutrients obtained from the soil, and another 5 are elements obtained from the soil that are needed by some, but not all, plants. Therefore, soils that provide a healthy, nutrient-rich growth medium for plants will result in plant tissues that contain many of the elements required for human life. Most elements necessary for human life are obtained from either plant or animal tissues (Shetty, 2009; Buol, 2008; Combs, 2005). Plant tissues are among the most important sources of Ca, P, Mg, K, Cu, Zn, Se, Mn, and Mo in the human diet (Table 4), and these elements are obtained by plants from the soil.

Table 4: Essential elements and the sources of Human Life

Elements	Important Sources
Calcium (Ca)	Kale/leaf cabbage (Brassica oleracea), collards (loose-leafed cultivars of Brassica oleracea), mustard greens (Brassica juncea), broccoli (Brassica oleracea var. italica)
Copper (Cu)	Beans (family Fabaceae), peas (Pisum sativum), lentils (Lens culinaris) , whole grains, nuts, peanuts (Arachis hypogaea) , mushrooms, chocolate

Iodine (I)	Vegetables, cereals, fruit
Potassium (K)	Fruits, cereals, vegetables, beans, peas, lentils
Magnesium (Mg)	Seeds, nuts, beans, peas, lentils, whole grains, dark green vegetables
Manganese (Mn)	Whole grains, beans, peas, lentils, nuts, tea (Camellia sinensis)
Molybdenum (Mo)	Beans, peas, lentils, dark green leafy vegetables
Phosphorus (P)	Nuts, beans, peas, lentils, grains
Selenium (Se)	Grain products, nuts, garlic (Allium sativum), broccoli (if grown in high-Se soils)
Zinc (Zn)	Nuts, whole grains, beans, peas, lentils

Source: Modified from Brevik (2013)

Different abnormalities like stunted growth, anorexia, skin lesions, diarrhoea, and impaired immune and cognitive functions may happen from zinc deficiency (Combs, 2005; Abrahams,2002). Zinc-deficient soils are widespread worldwide; therefore, such soils require remedial measures following recommended doses of fertilizers (RDFs) to protect human health. Many toxic elements (As, Cd, Fe, Zn, Cu, Cr, Se) are reported to affect human health. Soil health and human health are linked. Cadmium (Cd) toxicity causing itai-itai disease in Japan is a classic example of the problems created by high Cd levels (Nordberg and Cherian, 2005). Although such elements are required in small quantities in the human body, there are apprehensions about synergistic/antagonistic effects between different elements. Studies on multi nutrients both in soils and the human body are suggested.

5.3 Soil nutrients and different animal products

Animal products including flesh (meat), milk, eggs, and others fed on products grown in soils. Unhealthy soils might create inappropriate animal products for human consumption causing damage to health. Besides, there are cases when a few elements (Cd, Pb, Se, and Hg) can accumulate in animal products at levels that are not detrimental to animal health but are harmful to human health if those animal products are consumed (Klasing et al., 2005). Human diet and type of elements are shown in Table 5. Intensive agriculture has depleted many nutrient elements which have a profound influence on plant and human health and might cause different disorders if deficient (Table 6).

Table 5: Some Important Animal-Product Sources of Elements Essential to Human Life

Element	Important Sources
Calcium (Ca)	Dairy products
Chlorine (Cl)	Dairy products, meats, eggs
Copper (Cu)	Organ meats
Iron (Fe)	Meats, especially red meat
Potassium (K)	Dairy products, meats
Molybdenum (Mo)	Organ meats
Sodium (Na)	Dairy products, meats, eggs
Phosphorus (P)	Meats, eggs, dairy products
Selenium (Se)	Meats from Se-fed livestock
Zinc (Zn)	Meats, organ meats

Source: Modified from Brevik (2013)

Table 6: Selected elements and their role and deficiency symptoms

Elements	Role in plant and human health	Deficiency impacts
Copper (Cu)	Immune, Nervous, and Skeletal systems	Hypochromic anaemia, neutropenia
Iodine (I)	A crucial ingredient in thyroid hormone, mental development	Mental retardation
Manganese (Mn)	Enzyme activator	Poor reproductive performance, growth retardation
Molybdenum (Mo)	Breakdown of toxic Sulphite built up, Fight Cancer	Retarded weight gain
Zinc (Zn)	Protein synthesis, cell division, and growth	Affects the skin, gastrointestinal, nervous, skeletal, and reproductive systems
Iron (Fe)	Metabolism, cellular growth	Anaemia, immune function

Boron (B)	Binding cellular membranes, Immune function, Metabolism of steroid hormones	Impaired calcium utilization of bones

Data source: (Shukla and Pakhare, 2015)

5.4 Issues related to elements causing soil toxicity

In addition to providing elements at levels that are essential for human health, soils can also provide other elements [lead (Pb), cadmium (Cd), Arsenic (As), uranium (U), radium (Ra), and radon (Rn)], which might affect human health. Many other organic compounds are applied externally for better crop yield, and also from various other sources like industrial effluents causing various detrimental effects on human health.

5.5 Health effects from exposure to heavy metals in soil

The uptake of heavy metals by plants and subsequent accumulation along the food chain is a potential threat to human health. The consumption of heavy metal-contaminated food can seriously deplete some essential nutrients in the body that are further responsible for decreasing immunological deficiencies, intra-uterine growth retardation, disabilities associated with malnutrition, and high prevalence of upper gastro-intestinal cancer rates (Khan et al., 2008). Heavy metal accumulation is generally geogenic but could also be anthropogenic; for details on soil heavy metals and human health the review of Brevik 2013) may be helpful for enthusiastic readers. A list of health problems associated with selected heavy metals and some of the common sources of those metals are given in Table 7.

Table 7: Heavy Metal-related Human Health Problems

Heavy Metal	Anthropogenic Sources	Health Problems
Hg	Electrical switches, fluorescent light bulbs, mercury lamps, batteries, thermometers, dental fillings, burning of coal and fuel oil, medical wastes, pesticides, mining	Central nervous system damage, coordination difficulties, eyesight problems, problems with the sense of touch, liver, heart, and kidney damage

Pb	Batteries, solder, ammunition, pigments, ceramic glaze, hair coloring, fishing equipment, leaded gasoline, mining, plumbing, burning of coal	Neurological impacts, lowers IQ and attention spans, impaired hand-eye coordination, encephalopathy, deterioration of bones, hypertension
Cd	Zinc smelting, burning coal or Cd containing garbage, rechargeable batteries, pigments, TVs, solar cells, steel, phosphorus fertilizer, metal plating, water pipes	Liver and kidney damage, carcinogenic, low bone density
As	Pesticides, mining and smelting of gold, lead, copper, and nickel, iron, and steel production, burning of coal, wood preservatives	Gastrointestinal damage, skin damage, carcinogenic, heart, neurologic, and liver damage
Cr	Electroplating, corrosion protection, leather tanning, wood preservative, a cooling-tower water additive	Carcinogenic, gastro-intestinal disorders, haemorrhagic diathesis, convulsions

Source: Modified from Brevik (2013)

5.6 Soil biology

For Indian soils, soil microbiological information was first dove-tailed into the soil information system for various uses and their potential applications by a host of authors (Bhattacharyya, 2021a, b; 2022; Bhattacharyya et al. 2014a, b; Srivastava, 2014; Velmourougane et al., 2014a,b). Soil is the habitat of organisms which include microbes and higher animals. These are highly beneficial to soil's physical and chemical processes that influence soil fertility and productivity. The burrowing animals redistribute soil materials from deeper layers to reach the surface. These animals fill the soil through their burrowing action. Their faeces serve

as rich sources of soil nutrients. Several species of fungi in the soil are important in the decomposition of organic materials to form humus and thus help form soil aggregates. Other important microbes include actinomycetes, algae, bacteria, nematodes, and protozoa. Actinomycetes give soil its characteristic earthy aroma when it rains.

Soil has a diverse system of biological characteristics often termed soil biodiversity. This system is beneficial for plant growth, including crop production. With increased diversity, the decomposition of organic matter and the release of more nutrients are possible. Table 3 shows different soil organisms and their role.

5.7 Soils and human health: Soil gene pool

Since soil is a shelter for a large number of organisms, it can be considered a genetic reserve or gene pool, ensuring the conditions for the existence of biodiversity in the edaphic environment. Soil as a gene pool was used first by D. Waksman in 1940 (Nobel Laureate in 1952) to isolate an antibiotic compound from the actinomycetes. Antibiotic groups extracted from the soil are aminoglycosides, glycopeptides, tetracycline, and cephalosporin. A schematic diagram shows how soil elements enter the plant, animal, and human food chain (Figure 22) (Brevik, 2013). An organized soil information system can be helpful for medical practitioners and nutritionists (Bhattacharyya 2021b). Depending on the type of soil and its uses and abuses these could be a source of toxic elements and could be the cause of health hazards. One of the ways of deliberate and direct ingestion is called geophagy (described later) (Figure 22).

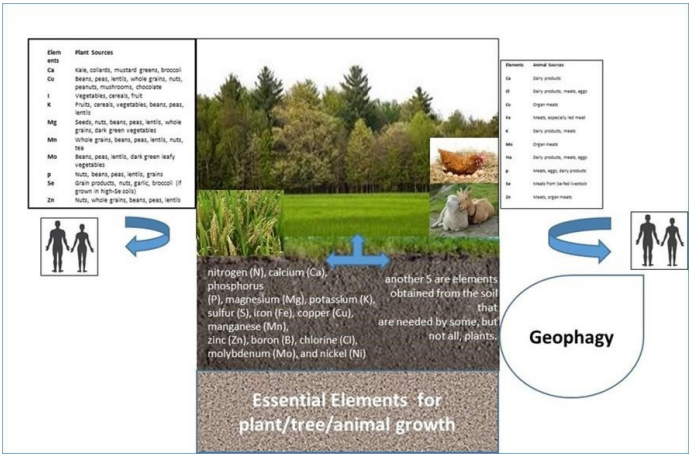


Figure 22: Schematic diagram showing soil elements necessary for plants and animals ultimately influencing human health (information from Brevik and Sauer, 2015) (Source: Bhattacharyya (2021b))

6. Fertility and its quality: Then and Now

6.1 Soil fertility and quality: Ancient concepts

The beginning of the cultivation of plants for the food of human beings marks the dawn of agriculture. It was several thousand years BCE, and before that, people were exclusively nomadic in their habits.

Information on writing (2500 BCE) mentions land/soil fertility in the early civilization of Mesopotamia, situated between the Tigris and Euphrates rivers in today's Iraq. The Greek historian Herodotus reported in his travel diary the phenomenal yield of crops obtained by the inhabitants of Mesopotamia. The probable reason was irrigation, soil fertility, and the annual flooding by the river (to bring fresh sediments to help crop growth). Theophrastus (300 BCE) mentioned the richness and good fertility of the Tigris alluvium. People gradually learnt that continuous farming could make soils poor, affecting the crop yield. Such observations must have developed the concept of the external addition of manures (animal and vegetable sources).

In the Odyssey, the Greek poem (900- 700 BCE) mentioned the manuring process. Similarly, for thin soils (shallow soils), abundant manuring was recommended by Theophrastus (372-282 BC), who developed a list to choose the manure in terms of their richness for humans> swine>goat>sheep>cow>ox-en>horse. The importance of green manure crops was also recognized soon. In Macedonia, a bean crop (Vicia faba) was ploughed back into soils by the farmers to increase crop production in the enriched soils. Virgil (70-19 BC) also advocated the application of legumes to improve soil fertility.

Ancient people were also aware of applying fertilizers (in mineral form) other than manure. Adding fertile soils to relatively infertile soils led to higher soil fertility. Besides, mixing coarse-textured soils with the finer components also improved soil water-air conditions to affect soil fertility, as observed by Theophrastus[20] . In ancient times, people were aware of the methods of predicting the soil's suitability for crops. Virgil[21], for example, opined black soils were better for corn. Although people thought black soils were more fertile than light or grey-coloured soils, others believed soil structure, texture and acidity were important to determine soil fertility.

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[20]Theophrastus (371 – 287 BCE), from Greece was the successor to Aristotle in the Peripatetic school. His interests included biology, physics, ethics, and metaphysics.

[21]Virgil (Publius Vergilius Maro) (70 –19 BCE) was an ancient Roman poet. Virgil's work, ranked as one of Rome's greatest poets, has had a great influence on Western literature.

Historically, crop production has been based on plant nutrients already present in soils. Although additional plant nutrients have increased since 1950 (Tisdale and Nelson,1975), most crops continue to be grown based on mining the soils for nutrients by resource-poor farmers. The problem of predicting plant nutrient needs has been under study for a long time. Sir Humphrey Davy, in 1813 stated that if the soil is unproductive, the cause of sterility may be determined by chemical analyses. Several techniques are suggested assessing soil fertility, such as nutrient deficiency symptoms of plants, plant analyses, the biological test of substrate used for crop production, and soil tests by chemical analyses. New problems in soil fertility are gradually rising. These problems require refinement of the present recommendation as well as methodology. This will be discussed in light of soil fertility and its quality in the following paragraphs.

6.2 Soil fertility and quality: Modern concepts

To sharpen the concept of soil fertility and soil quality (SQ) and its assessment, soil erosion, organic matter loss, low fertility soil contamination, and water and air quality deterioration are major critical issues. This is due to massive pressure on land and soils for more food for the ever-increasing population. Various groups of researchers defined soil quality as follows (i) the capacity of the soil to function (common literature), (ii) the capacity of a specific kind of soil to function within natural or managed ecosystem boundaries, to sustain plant and animal productivity, to maintain or enhance water quality, and support human health and habitation (Soil Science Society of America, SSSA), (iii) three-legged stool, the function and balance of which requires an integration of three major components – sustained biological productivity, environmental quality, and plant and animal health (SSSA conceptualizsed), and (iv) soil capacity promoting plant growth, protect watershed protection controlling climatic parameters like rainfall, and prevent water and air pollution using various techniques (The National Research Council, USA).

Defining soil quality conceptually, let alone quantitatively, is a complex task. Some have argued that we should assess soil health in much the same manner as physicians evaluate human health, using the following six-step processes to (a) identify symptoms, (b) identify and measure vital signs, (c) make a provisional diagnosis, (d) conduct tests to verify the diagnosis, (e) make a prognosis, and (f) prescribe a treatment of the land. Soil quality, dependent on soil fertility is assessed by measuring Soil Quality Index (SQI) (Doran and Parkin,1994). A particular method

may not be applicable for all conditions to measure soil quality index. In some places, it might require seeking an expert opinion (EO) from those who have vast working experience with soils, and their use, crop, and natural resource management (Ray et al., 2014). Soil quality is discussed in brief in the following paragraphs.

6.3 Soil quality in the Indo-Gangetic Plains (IGP): An example

6.3.1 History of the IGP

The Indo-Gangetic Plains (IGP), also known as the North Indian River Plain, is a 700-thousand square kilometre (172-million-acre) fertile plains that cover many regions in the Indian subcontinent, a few areas of Pakistan, entire Bangladesh, and Nepal (southern part) (Taneja et al., 2014). The region is named after the Indus and the Ganges rivers, which encompass several large urban areas. The IGP is bound by the Himalayas (in the north), providing water in the rivers throughout the year and enriching alluvium soils. The Peninsular Plateau marks the southern edge of the plain. On the West rises the Iranian Plateau. Many developed cities of India (New Delhi and Kolkata), Pakistan (Lahore and Karachi), and Bangladesh (Dhaka) are located in this vast alluvial plain.

This region represents the Indus Valley Civilization, which was responsible for the birth of the ancient culture of the Indian subcontinent. This vast tract of alluvial plains housing excellent quality fertile soils helped the rise of several empires, kingdoms and/or dynasties such as the Maurya Empire, Kushan Empire, Gupta Empire, Pala Empire, Imperial Kannauj, Delhi Sultanates, the Mughal Empire, and the Maratha Empire all of which had their demographic and political centres in the IGP.

During the Vedic and Epic eras of Indian history, this region was referred to as Aryavarta (Land of the Aryans). According to the Manusmṛti (2.22), Aryavarta is the "tract between the Himalayas and the Vindhyan ranges, from the Eastern Sea (Bay of Bengal) to the Western Sea (Arabian Sea)" (Cook, 2014). The region is also referred to historically as Hindustan or the Land of the Hindus. The word Hindu and Stan in Hindustan are Persian words; the former descends from the Sanskrit word Sindhu while the latter, which means a place, is a cognate of the Sanskrit word Sthan, which was later used to signify the whole of the Indian subcontinent (Anonymous, 2022n).

Archaeological investigations along many important sites in the southern, central, and western parts of the IGP suggest considerable progress from incipient agricultural activities to well-developed agricultural practices over the last 10,000 years (Anonymous, 2022a). According to recorded information from ancient India

from 2500 BCE to 600 CE, vast knowledge acquired by the then agriculturists by experience had become tradition, and the same has been passed on from one generation to the next. However, a major part of this has been forgotten or lost and thus has become a story of the past (Raychaudhuri, 1975; Velayutham et al., 2016).

6.3.2 Indo-Gangetic Plains (IGP): Setting

The Indo-Gangetic Plains (IGP) is one of the most extensive and fertile alluvial plains in the world. The courses of the river Ganges and the deposition of alluvium have been governed by the various tectonic events in its history which are active even today. The soils of the IGP were developed from the alluvium of the rivers Ganga, Yamuna, Indus, Ramganga, Ghagra, Rapti, Gandak, Bhagirathi, Silai, Damodar, Ajay, and Kosi. The IGP covers the Indian states of Rajasthan, Punjab, Haryana, Uttar Pradesh, Bihar, West Bengal, and Tripura. It covers an area of about 50.01 million ha and represents eight (8) agro-ecological regions (AERs) and seventeen (17) agro-ecological sub-regions (AESRs) of the country. The soils belong to the Entisols, Inceptisols, Alfisols, Aridisols, Mollisols, and Vertisols orders of US soil taxonomy.

It is imperative to understand the fundamental processes that govern the formation of these soils and their influence on the land use/land cover and change direction subjected to taking into account biophysical, socio-economic, and demographic factors that drive them. There is a need to analyse past trends to understand the role of biophysical factors, socio-economic perceptions, and other factors leading to the emergence of characteristics of the present agricultural systems characterized by decline/stagnation in yield and deterioration in soil health. Out of these properties, the most fundamental one with enormous value and importance to influence the other dynamic factors is the biophysical factor, i.e., the quality of soil substrate for sustenance.

Several workers have identified various soil-forming processes, such as the effect of temperature and rainfall, which have helped develop different types of soils qualifying to be Entisols (recently formed soils), Inceptisols (Inception of soil formation), Aridisols (Dryland soils), Mollisols (Brown Forest soils), and Alfisols (Well-developed soils) due to various soil forming process such as calcification, leaching, lessivage, salinization and alkalinization, gleization, and homogenization. In this regard, the changes in levels of carbon in soils between 1980 and 2005 were monitored and revealed that a possible decline in soil organic carbon is the root of productivity deterioration. However, datasets for 1980 and 2005 indicated an overall increase in soil organic carbon (SOC) due to an increase in soil inorganic carbon (SIC) which is, however, a negative indicator of soil productivity. The other major cause of productivity decline is the chemical degradation of soils.

6.4 Environmental soil quality

Soil pollution is a multifaceted and multidisciplinary subject. Many inputs used in agricultural production (fertilizers, pesticides, herbicides, household wastes, poor-quality irrigation water, and urban encroachment inputs) can be pollutants if not appropriately managed. Soils in non-agricultural lands can be polluted by atmospheric depositions, improper disposal of wastes and by-products, or by accident, as in the case of chemical spills or natural calamities. Many activities in society can contaminate soils and lead to environmental degradation.

Soil testing has traditionally been used to evaluate the soil limitations to agronomic crop performance imposed by nutrient deficiencies, pH, and soluble salts and to guide the recommendation process so that these limitations could be eliminated economically and without impacting the quality of our environment. Environmental soil testing is a much more ambiguous process than agricultural soil testing because it is usually quite challenging to quantify the meaning of the term environmentally unacceptable. The rising interest in environmental protection in many areas of the world has promoted an increased effort to use soil testing to assess the risks posed by soils to other sectors of the environment, particularly ground and surface water systems (Bhattacharyya, 2021 b).

Potentially toxic trace elements are an environmental issue because some plant nutrients (Cu, Mo, and Zn) and nonessential elements (As, Cd, Cr, Hg, Ni, Pb, and Se) are toxic to plants, animals, or humans. Some soils may be highly polluted with toxic elements due to mismanagement of potentially beneficial wastes, by an accidental spill or discharge, or as a result of industrial activity such as mining or smelting. Contamination occurs when a substance is present at concentrations higher than it would occur naturally. Still, no adverse effect on an organism is apparent while pollution implies not only an elevated concentration in the soil but documenting the adverse effects on some organisms. Pollution is the introduction of contaminants into the environment that causes instability, disorder, harm, or discomfort to the physical systems for the living organisms. A classification of pollutants in soil and their environmental symptoms and concern is depicted in Table 8.

Table 8: Classification of potential soil pollutants and their environmental symptoms (Bhattacharyya 2021a)

Pollutant or environmental concern	Examples	Primary environmental symptom or concern
Nutrients	N and P in commercial fertilizers, manures, biosolids, wastewater treatment effluent	Eutrophication, contaminated drinking water
Pesticides	Insecticides, herbicides, and fungicides	Ecological risks, contaminated drinking water, human health
Hazardous organic chemicals	Fuels, solvents, volatile organic compounds	Ecological risks, contaminated drinking water, human health on exposure
Hazardous materials	Strong acids and bases	Degradation of structures
Acidification	Acid precipitation, acid mine drainage	Ecological risk, Human health concerns
Salinity or sodicity	Saline irrigation water, saltwater intrusion	Loss of soil productivity, Turbidity, eutrophication
Trace elements	Heavy metals, elements normally present at low concentrations in soils or plants	Human health concerns
Sediments Particulars	Eroded soil in surface waters, Soot, dust from wind erosion, volcanic dust, ash	Visibility, respiration
Greenhouse gases, Smog-forming compounds, Radionuclides	Carbon dioxide, methane, and other gases, Ozone, secondary products of fuel combustion	Global climate change, Effect on all living organisms, Human health concerns

6.5 Soil pollution and soil quality

A valid soil quality index would help to interpret data from different soil measurements and show whether management and land use have the desired results for productivity, environmental protection, and health. A simple scoring approach can be used to help users decide whether to accept or reject a potential soil quality indicator for degraded or polluted soils using the following

A = sum of (S, U, M, I, R)

where A = acceptance score for indicator, S = sensitivity of indicator to degradation or remediation process, U = ease of understanding of indicator value, M = Ease and/or cost-effectiveness of measurement of soil indicator, I = predictable influence of properties on soil, plant, and animal health, and productivity, and R = relationship to ecosystem processes (especially those reflecting wider aspects of environmental quality and sustainability). Soil quality can be viewed from two perspectives, such as, (i) the degree to which soil function is impaired by contaminants, and (ii) the ability of the soil to bind, detoxify and degrade contaminants (Bhattacharyya, 2021 b).

6.6 Role of fibrous minerals in governing soil quality

Soils provide the basic materials for plant growth and it has both yield-reducing and yield favouring potential. However, only a few are available on the index soil properties of fibrous minerals-containing soils on crop yields in the semi-arid tropical (SAT) regions. These minerals in soils are mostly palygorskite and sepiolite. Many reviews on the occurrence of palygorskite in soils from the semi-arid tropical (SAT) regions of the world are available. Some authors have suggested that the soil palygorskite is pedogenic whereas others have reported this mineral as inherited from the soil parent materials. Palygorskite is reported to be stable at very high Si and Mg levels when the pH was approximately 9.0. Palygorskite is, on many occasions, found in association with smectite (a mineral with a shrink-swell character), and its formation is often thought to be at the expense of the latter. Its formation is also suggested through an intense dissolution process of smectite that resulted in an increase in Al and Fe ions and Mg/Ca ratio favouring the formation and an internal adjustment in the structure of smectite. The presence of palygorskite in the black soils is of non-pedogenic origin and its formation at the expense of smectite may not be a common pedogenic event. Palygorskite particles move downward in soils preferentially over smectite and eventually clog the soil pores. Therefore, palygorskite containing black soils with high Mg ions on the exchange sites causes dispersion of the clay colloids that form a 3D mesh in the soil matrix. Given the poor drainage conditions of these soils and loss of productivity, non-sodic and sodic black soils with palygorskite minerals

should be considered naturally degraded soils, where soil drainage is impaired by the presence of palygorskite alone in non-sodic soils. In contrast, in sodic soils, such impairment is caused by palygorskite and high ESP.

Thus, palygorskite in semi-arid tropical (SAT) black soils is a non-pedogenic entity even though palygorskite is reported to be a significant phase, or phases, of redistribution of smectite-rich alluvium of the weathering Deccan basalt in the lower physiographic positions, i.e., in the lower piedmont plains or valleys or in micro depressions. During such erosional and depositional episodes, minor minerals (quartz, K-feldspar, chlorite, and micas) that have no legacy to the Deccan basalt were incorporated due to the exhumation of other rock formations that underlie the Deccan basalt which might have included the palygorskite-rich clay sediments of the intertrappean (Bhattacharyya, 2021 b).

7. Sustainable practices

7.1 Traditional sustainable practices

Traditional sustainable practices are discussed concerning agriculture and natural resource management. Conventional agriculture has adaptive and mitigation abilities towards various anthropogenic threats (Watson 2019). These practices help manage natural resources and augment crop production. The traditional farming system is based on the ecological principle and the interaction between the human environment and existing natural resources. The uniqueness of traditional agriculture is its ecologically benign nature, public acceptability, and environmental and economic feasibility (Patel et al., 2020). The sustainability potential of traditional agriculture mainly includes three aspects such as social equality, economic profitability, and environmental health (Fig. 23).

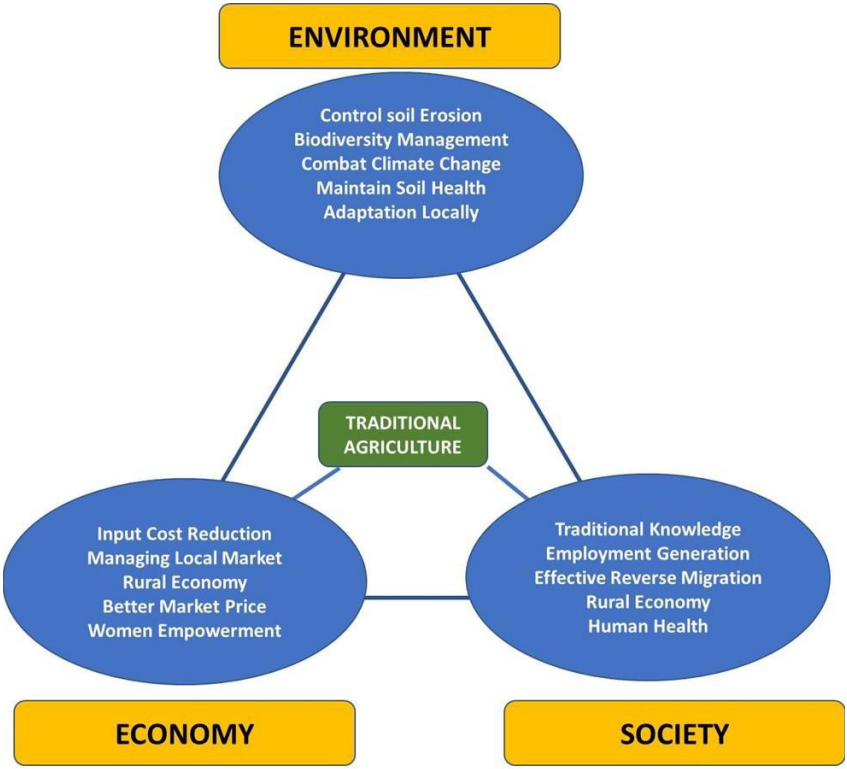

Figure 23: Sustainable agriculture and its benefits (Adapted from Patel et al., 2020)

Various traditional agricultural practices are reported from across India with a distinct feature in the context of environmental safeguarding towards synthetic fertilizer contamination of agro-ecosystem (Joshi and Singh 2006). Traditional agricultural practices may be grouped into four categories: cultivation, plant disease, pest management, and crop protection (Table 9; Figure 24).

Table 9: Traditional agricultural practices for cultivation

Categories	Practices	Features
Based on cultivation	Organic composting	Process of microbiological degradation and recycling of waste into FYM
	Livestock-integrated	The oldest practices: mainstay of ancient agriculture
	Agroforestry	Tree-integrated agriculture
	Mixed/intercropping	Crop diversity: soil nutrient balance, defenses against pests, and extreme weather
	Crop rotation	Control of weeds, pests, and diseases
	Pasture cover or grazing	Rich source of microbial and arthropod diversity
	Home Gardening	Repository of native diversity of fruits, ornamental and medicinal plants
Based on plant disease and pest management	Summer ploughing/ resting	Pest and disease are managed
	Use of a mixture of ash and manure	Soil and pest management
	Push-pull method of pest management	Similar to intercropping; Push plant which is grown with cash crop has a preference to push only pest organism

Based on plant disease and pest management	Traditional methods of grain storage	Restrict the pests from destroying stored seed
	Biological pest and weed control	In traditional agriculture, about 90% of the farmers control the weeds and pests by handpicking and hoeing
Based on crop protection	local and sustainable protection methods	Crops get better protection
	Scarecrow	
	barricading bamboo pole and rice straw rope	
	Protection against bird attack	
	Rat trap	

Data source: (Patel et al., 2020)

Figure 24: Different traditional crop pest management practices: a, b Vegetative barricading for animal protection through the use of rice straw and branches of a spiny plant. c Sitting branch in the wheat field inviting bird predation. d Scarecrow for crop protection (Source: Patel et al., 2020)

7.2 Sustainable practices for development goals

UN Sustainable Development Goal (SDG) 17 visualises the partnerships for the goals to enhance the Global Partnership for Sustainable Development. The SDG enabled multi-stakeholder partnerships to mobilise and share knowledge, expertise, technology, and financial resources, to support the achievement of the SDGs in all countries, in general, and developing countries like India and others, in particular. Digital media and/e-extension can achieve the SDGs in India and other countries.

FAO suggested a 15- point strategy to modernize extension systems at lower levels. Other than many, the point which flags performing extension services with a few staff appears as the typical scenario in most countries. Outsourcing is an important option. It also insists on using information technology tools and media, but with educated human backstopping, which is all about e-extension (e-E). Treating extension finance and extension delivery would be two separate functions.

The history of information and communication technology (ICT) for extension in agriculture dates back to the use of radio and much before that by just personal communication, as an example in Sweden during the 1800s. These channels help primarily in the one-way dissemination of topical and general information. Farmers need farm and season-specific information. Attempts to make radio and television more interactive have proved successful and make these media more accessible to the farmers. But it is the IT revolution which has put mobile and internet in the hands of the farmers. The potential of IT was found to be harnessed by the government and different organizations for the best results. Several initiatives have been taken up by government departments for advancing e-E. A review of the current status is detailed elsewhere (Bhattacharyya 2018a, b;2021a, b). The SDG 15 Goals are shown in Figure 25.

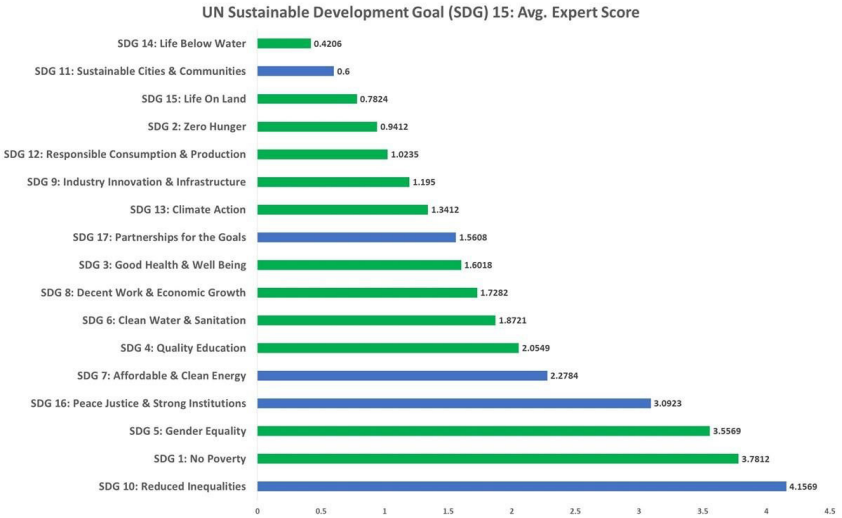

Figure 25: UN Sustainable Development Goal (SDG) 15 shows the average expert score (Green colour shows those which are perhaps directly related to agriculture) (The scores reflect the average ordering for all options related to an SDG) (Source: https://www.sdgsinorder.org/goals)

The Sustainable Development Goals (SDGs) gave soil scientists an extraordinary opportunity to raise awareness about the importance of soils in achieving multiple SDGs and contributing to existing challenges. Global developments such as an increase in population, a decrease in resources including water, land, and nutrients, and climate change restrict our capacity to increase food production while sustainably managing our natural resources. Furthermore, issues such as land degradation, soil erosion, and loss of organic matter are deeply intertwined with reduced environmental quality to affect the normal livelihoods of the whole world. There are guidelines for the SDGs to eradicate poverty. Soils, food production, and healthy living are connected with SDG 2 (zero hunger), suggesting the level of importance put towards soils in the overall programmes of the SDGs. Nonetheless, soils fulfil a large number of functions and ecosystem services that explicitly bind them with other goals such as SDG 1 (No poverty), SDG 3 (Good health and well-being), SDG 6 (Clean water and sanitation), SDG 13 (Climate action), and SDG 15 (Life on land). It has been agreed upon that cross-sector integrated work is imperative and that soils could be an important issue in achieving the goals of the SDGs. (https://flores.unu.edu/en/news/news/the-role-of-soils-inachieving-the-sdgs.html) (Figure 26).

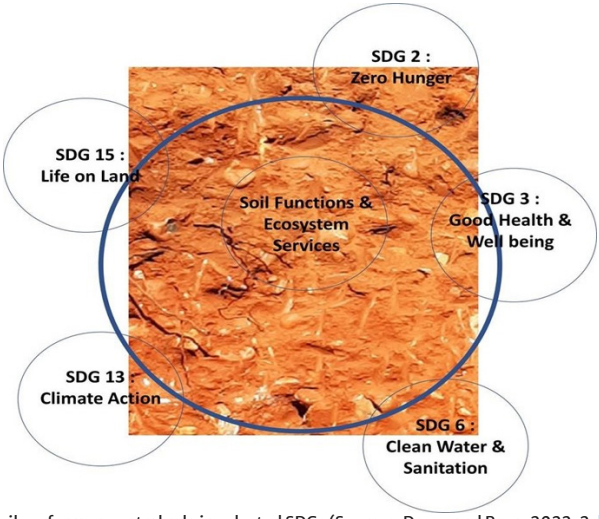

Figure 26: Soil performs a central role in selected SDGs (Sources: Dazzy and Papa, 2022; 2. https://flores.unu.edu/en/news/news/the role of soils in achieving the sdgs.html

7.3 Soil purification practices

Soil acts as a filter for water used for almost all biochemical reactions in the pedosphere. Besides, soils filter water and make it consumable by all living beings (Figure 27). Water is essential for all biological, chemical, and physical transformation processes. It controls profile differentiation through i) percolation (rainfall> evaporation), ii) ascent (potential evaporation < rainfall), iii) surface erosion, and iv) water-logging, which affects the process of translocation of materials from the topsoil to sub-soil. Various factors such as rainfall, temperature, and seasonal variation characterize an area in terms of its bioclimatic systems, viz. per-humid, humid, sub-humid, semi-arid, or arid. The extent to which climate influences soil formation and profile differentiation depend on whether or to what extent water penetrates the soil. And since it varies, so do the properties of soils in different bioclimatic systems.

One of the most exciting approaches for soil purification is bioremediation. In bioremediation, microorganisms are used to break down the contaminants within the soil. Bioremediation is typically used to treat organic contaminants such as oils and petroleum-based fuels. (Soil purification practices - Search (bing.com)). The major difficulty in bioremediation is the availability of contaminants, as these hydrophobic compounds bond with soil particles and have low solubility in water. To enhance the contaminants' contact with micro-organisms, and thus biodegradation, surfactants are utilized. Surfactants are used to enhance the

desorption and solubilisation of petroleum hydrocarbons, thereby facilitating their assimilation by micro-organisms.

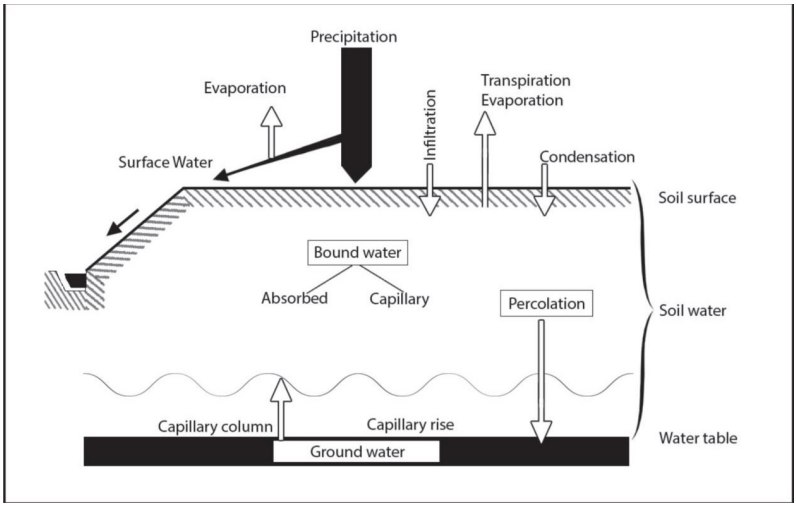

Figure 27: Soil acts as a filter as is seen by the fate of water after it reaches the soil environment (Source: Bhattacharyya and Pal, 2015)

7.4 Use of soils in social and religious traditions

Soil is the source of clay, and the most significant and universal artistic and practical use of clay is for ceramics and pottery. Soil and its gifts are used both literally and symbolically by artists and artisans as well. They have created everything from bricks to tiles to dishes to ornamental figurines and sculptures from clay. When artists aren't using soil resources as their medium, they often use the soil and its encompassing landscape as a subject in paintings (Szulczewski, 2015) (Figure 28). [(Use of soils in social and religious traditions - Search (bing.com)]. Hinduism and Buddhism believe that humans and nature are closely connected and that humans must respect the earth's bounty. A central tenet of Hindus is that since the world is a divine creation, all parts should be honoured, from insects to animals to the environment.

Figure 28: Use of soils in pottery in Ancient India, religious purpose, and in ceramics

(Source: Google sites)

7.5 Hindu festivals in India related to soils, trees and others

Hindus worship idols to seek divine blessings. Most of these festivals involve worshipping gods and goddesses. The idols used in such festivals are made up of soil; skilled and highly efficient groups of people involved in this profession of potteries show their fine art in the form of beautiful idols (Figure 31). Soil and earth are used in the Hindu religion synonymously in many cases. Since both are considered goddesses (Vasundhara/Vasudha meaning Mother Earth), any sacred work /festival starts with worshipping soil/earth. The most common among these is bhoomi puja (worshipping mother earth). The puja is performed to remove all the negativities and Vastu Doshas in the land.

Nature and cultural practices which are in perfect harmony with the environment have always been respected by the Indians. There are also numerous festivals in the Hindu religion that celebrate nature and passes on the importance of the preservation of the environment from one generation to the next. The first week of July marks Van Mahotsava (Festival of Forests) across India. The basic purpose of this festival remains to spread the knowledge of trees and their benefits for society to maintain ecological balance. As a part of this celebration, which started in 1950, tree plantation drives are conducted at various schools and communal grounds. Several events are organized. These are exhibitions, seminars, the distribution of saplings, and awareness walks (Figure 29).

Figure 29: Tree Plantation Festival (Vriksa Ropan) and Van Mahotsava in India.

While Van Mahotsavas are celebrated in pan India, several other regional festivals focus on worshipping nature and conserving the environment. Sarhul (worship of trees) is one such festival celebrated mainly in the tribal state of Jharkhand, India, by a group of tribes belonging to the Oraon, the Munda, and the Ho (Figure 30). This festival marks the beginning of the local new year and continues till spring (March).

Figure 30: Sarhul Festival in Jharkhand, India

India's Vedic culture has three aspects namely, philosophy, history, and all-important rituals. From the heights of metaphysics to their day-to-day understanding to the emotional release of bhakti through rituals, Indian festivals have been a vehicle of divine wisdom and thought. Swami Harshananda of the Ramakrishna Math in his book Hindu Festivals and Sacred Days, says that there are two main activities that channel our emotions. These are vrata (derived from the root word vrn meaning to choose), in which an individual bind oneself to a vow to propitiate a deity. The other is utsava which literally means to cause to move upward but has been used to mean festive celebration. These two actions form the basis of devotion in almost every ancient culture worldwide. In Swami Harshananda's words, "An overwhelming majority of Hindu festivals are not only vratas but also utsavas since the latter follows the former without exception." And both are closely connected to ahara (Food). The connection between mother earth and food has been an integral part of our civilization. Ahara is not merely sustenance to keep us alive. It is mother nature's nourishment of the mind and memory, the imprints of our ancestors, the seed of the new-born, the spirit of the family, land, river, sky, mountains, and universe. In Ayurveda, every grain of sand depends on Mother

nature's food. Without honouring her seasons, and her transitions, we cannot cull or garner the harmony that we so need to live.

The total number of vratas and ustavas is listed in the Chaturvarga cintmani of Hemadri (13th century) and is around 700 and all these are listed as per the lunar calendar. One of the most popular is Makara Sankranti (or Uttarayana Punyakalam). Swami Harshananda explains that Sankranti means "the (apparent) passage of the sun from one rasi (a sign of the zodiac) to the next following one and hence the rasi in which the sun enters is designated as the Sankranti of that name, like Mesa Sankranti, Vrsabha Sankranti and so on." Makara Sankranti which usually falls on January 14th, from which the northern journey of the sun (uttaraayana) starts, is considered very sacred. The other is the Karkataka Sankranti which marks the southern journey of the sun (dakshinayana).

7.6 Technologies used for soil management

7.6.1 Vedic agriculture in ancient India

To make the soil cultivable many methods are suggested. One such is the angara preparation involving the preparation of earthworms seeding using the soil beneath the banyan tree or any soil rich in earthworms (@ 15 kg of soil per acre of farmland) (Anonymous 2022o). Vedic literature suggests that Ancient India progressed in science, mathematics, civilization, and agriculture. The Vedic people were skilled in cultivation. The Hindu people strongly followed the traditions and cultures so that every practice of agriculture was associated with these religious customs. The people only started agricultural practices such as ploughing, sowing, reaping, and harvesting on auspicious days. Few people made the crop fields their modern laboratories and studied the nature of crops and plants using the knowledge of the weather and monsoons.

The Vedic people cultivated the main food items like wheat, barley, and other edible nuts. Rains, six seasons, and cattle were part of the hymns to describe their importance. During the Vedic era, people were knowledgeable about the science and autotrophism of plants to understand the role of plants in preparing their food. The use of the Sun and its energy to raise a bounty of crops was known in this era. The Atharva Veda narrated the art of manuring, its preparation, and its application in soils to maintain soil fertility. People were aware of the importance and art of cultivation. Ancient books mention the various crops, their classification (edible plants, creepers, and medicinal plants), nature and benefits, functions of trees, and their different parts (twigs, flowers, leaves, and fruits).

Vedic agriculture technology is mentioned in Rig Veda, Krishi-Parashara[22] , Manusmriti[23], Agni Purana,[24] and Vriksha Ayurveda[25] and describes how these modes of agriculture follow the rules of Nature showing due importance to the five of its elements viz., earth, water, air, fire, and sky. Vedic agriculture describes the synchronization method with living and non-living objects. It advocates the concept of saha-astitva (mutual co-existence) with living and non-living entities without dominance or exploitation.

Vedic farming technology is a crop production system that advocates rejecting the use of chemical fertilizers, pesticides, and chemical growth regulators and instead encourage the application of natural ingredients on-farm organic inputs and also natural/ biological/ mechanical pest control and plant protection measures with minimal use of permissible natural minerals. This technology, thus, advocates the mantra of healthy soils, resulting in healthy food, in a healthy environment inhabited by healthy people and animals (both macro and micro).

7.7 Promoting conservation and protection of environment and natural resources

Environment as a part of nature has been a subject of the Vedas, consisting of soil/earth, air, and water. A brief mention is made about the Vedas and the environment as their subjects and concern in ancient times, followed by a few shlokas related to preserving natural resources.

[22]Krishi-Parashara: It is a compilation of the original text in Sanskrit detailing the meteorological aspects and general agriculture. It also advocates a symbiotic relationship, organic farming techniques, crop management, holistic farming, and sustainable use of available resources.
[23]Manusmriti: The Manusmṛiti (Laws of Manu), is one of the many legal texts and Constitutions among the many Dharma sastras of Hinduism.
[24]Agni Purana: It is a Sanskrit text and one of the eighteen major Puranas of Hinduism and describes a detailed description to worship Gods like Brahma, Vishnu, Mahesh, and Suryadev.
[25]Vriksh Ayurveda (Ayurveda for trees): It is the ancient science of plant life. It describes all species of trees and their healthy growth and productivity and the process of optimizing the productivity of plants to control pests and diseases without using any chemicals.

7.7.1 Environmental science and the Vedas

The Vedas deal with knowledge with symbolic pictures close to life and nature. The Vedic texts provide the age-old traditions of worshipping nature. Although environmental science and ecology are disciplines of modern science, their origin is rooted in the Vedic and ancient Sanskrit literature (Anonymous, 2022p). The knowledge of Vedic seers about three basic elements of environment namely, water, air, and plants or herbs were known during the Vedic era as shown below from the Atharva Veda (Verse:18.1.17).

त्रीणिछन्दासि कवयो वि यतिरे पुरुरूप दशतं विश्वचक्षणम्।
आपो वाता ओषधयस्तान्येकस्मिन्भुवन आर्पतानि ॥

trīṇi chandāsi kavayo vi yatire pururūpa daśataṃ viśvacakṣaṇam |
āpo vātā oṣadhayas tāny ekasmin bhuvana āṛpatāni ||

Wise utilizes three elements variously which are varied, visible, and full of qualities. These are water, air, and plants or herbs. They exist in the world from the very beginning. They are called Chandansi meaning 'coverings' available everywhere.

Rig Vedic hymns are related mainly to the natural forces and address the deities (devata) to explain the phenomenon of nature and its aspects. During the Vedic era awareness about the environment, and its constituents suggested living in harmony with nature. To have a longer human life, environment should be unpolluted, clean, and peaceful as suggested by the Vedic sciences. The Vedic physical and metaphysical sciences advise 'the unity in diversity'. The Ishavasyopanishad[26] quotes the essence of comprehending the environment through this shloka that proves the origin of environmental studies from the Vedas.

ईशावास्यमिदं सर्वं यत्किञ्च जगत्यां जगत् ।
तेन त्यक्तेन भुञ्जीथा मा गृधः कस्य स्विद्धनम् ॥ १ ॥

īśāvāsyamidam sarvam yatkiñca jagatyām jagat |
tena tyaktena bhunjithā mā grdhah kasya sviddhanam || 1 ||

All this-whatsoever moves in this universe (and those that move not) is covered (indwelt or pervaded or enveloped or clothed) by the Lord. That renounced, enjoy. Do not covet anybody's wealth (Or – Do not covet, for whose is wealth?).

Source: https://shlokam.org/texts/ishavasya-1/

[26]Ishavasyopanishad: Ralph Griffith and Max Muller, each interprets the term "Isha" in the Upanishad interchangeably as "Lord" and "Self" (one's Self). Puqun Li translates the title of the Upanishad as "the ruler of the Self". The Upanishad is also known as Ishavasya Upanishad and Vajasaneyi Samhita Upanishad [Ishavasyopanishad - Search (bing.com)].

7.7.2 Conservation and protection of the environment

Nature and the necessary balance of nature and spirit are the mantra (teaching) of all the religions. The higher purpose of life is detachment from the world of nature and acquiring the qualities of the spiritual world (Anonymous, 2022q). The Hindu scriptures mention Vasudhaiva Kutumbakam (the entire Universe is one Family). Hindus regard all living creatures like mammals, animals, fishes, and birds as sacred since our souls have gone through these creatures to arrive at the birth of human beings. Hinduism known as an environmental-friendly religion. The Hindus believe in the presence of a divine in all the creations like rivers, mountains, lakes, animals, birds, flowers, minerals, stars, and planets. This is simply because the Divine reality is present as prana (soul), energy or power in every electron, particle, atom, cell, and in every indication of matter. Hinduism believes in the reincarnation (Samsara) determined by the law of karma and its idea of salvation suggesting freedom from this cycle of repeated birth and death. Hindu religion lays a lot of emphasis on environmental ethics, promoting its conservation and protection. It believes in the very concept of ecological responsibility to worship the Earth as our mother.

It considers all animals to have souls and champions their protection. Non-violence (ahimsa) has been a tradition. It believes that God is present in all nature, all creatures and in every human being regardless of their faith. The Bhagvad Gita advises us not to try to change the environment; improve it, or wrestle with it. Rather, if you feel it seems hostile (at times), tolerate it. From the above findings, it can also be observed that Mahabharat, Ramayan, Vedas, Upanishads, Bhagvad Gita and Purana aim at spreading messages for the preservation of the environment and ecological balance for a long time. Nature, or Earth, can never be a hostile element nor it can be conquered or dominated. In short, Hinduism forbids a man from exploiting nature and is taught to live in harmony with nature recognising that there is divine power in every element present on this earth.

7.8 Awareness through belief systems for soils and others

The practice of manuring and maintaining soil health was mentioned in Rig Veda. In Atharva Veda, the practice of green manure was also mentioned. Different belief systems support this connotation as shown below.

Sr. No.	Traditional belief	Remarks
1.	No one thrives by tilling sandy soil, and no one is ruined by ploughing clay	Tamil Proverb; Excessive tillage of sandy soils accelerates soil loss (Venkateswarlu, 1994)
2.	If ploughed soil is left to dry to one-fourth of its bulk (even without manure), it will produce a bumper yield.	Thirrukkural (Tamil guru) suggests. Aeration of soil is necessary for good crop production.
3.	Rich in manure, rich in fruit	Atharvaveda Samhita
4.	A field without manure is a cow without a calf	Ancient Telugu Proverb
5.	No fodder, no cattle; no cattle, no manures; no manure, no crop	Ancient Tamil Proverb

7.8.1 Belief systems

The ancient seers[27] of India scaled the pinnacles of science and spirituality. Hinduism is a way of life and is still a living civilization through its different belief systems (Anonymous, 2022r). Even with changing situations many such systems are in place and followed religiously in Hinduism. A few examples are shown here.

Lighting earthen lamps for prosperity

Earthen lamps are prepared from the fuller's earth[28] (soil) that is biodegradable, natural, and pollution-free material. These lamps are not harmful as are candles and/or other illuminating substances. Lighting these lamps is auspicious in Hinduism since this practice brings peace and tranquillity to the whole family other than beautifying the house and the ambience to make it free from insects and other unwanted creatures. This practice is very common during Deepawali[29] festival.

[27]Seer: A person of supposed supernatural insight who sees visions of the future.

[28]Fuller's earth: It is any clay material (aluminium magnesium silicate) that can decolourize oil or other liquids without the use of harsh chemical treatment.

[29]Deepawali (Festival of Lights): It is the festival of the people in India and other places. Deepawali festival symbolises the victory of good over evil, light over darkness, and knowledge over ignorance

Indian holy Trinity

Hinduism believes in three major gods to represent the Supreme Universe. They take care of three main parts of the human experience such as i) creation (Lord Brahma); ii) preservation (Lord Vishnu) and iii) destruction (Lord Shiva). Hinduism believes in one Supreme Being but recognises other gods as well.

Reincarnation

Hinduism believes that soul is transferred to another living being after death (Samsara[30]) which is reincarnation. Samsara means wandering or the world to realize a cyclic change. It is a fundamental concept in the Hindu religion and suggests the accepted belief that all living beings cyclically pass-through births and rebirths. A soul might keep being reborn depending on its karma till it becomes a part of the Supreme God, Bramha, to achieve moksha (Figure 31).

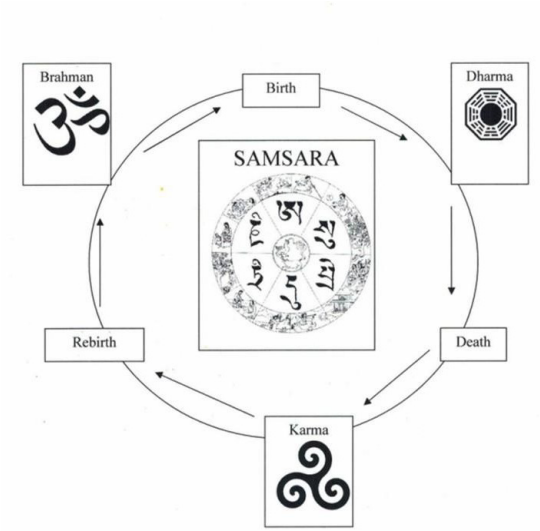

Figure 31: Hindu Beliefs of Birth, Rebirth through the cycle of Samsara (Anonymous, 2022r)

[30]Samsara: It means wandering or the world to realize a cyclic change. It is a fundamental concept in Hindu religions and suggests a belief that all living beings cyclically go through births and rebirths.

Hinduism is non-dogmatic religion

Hindu religion is non-dogmatic and permits people to worship any doctrines and rules they wish. It does not impose its beliefs on others.

Hinduism: Principles

The Hindu religion is principally based on two beliefs, namely,

1. Dharma: to perform moral and ethical duties. It is said that dharma protects those who protect it (Dharma Rakshati Rakshitah). Dharma has been described by this shloka

वेदः स्मृतः सदाचारः स्वस्य च प्रियमात्मनः।
एतच्चतुर्विधं प्राहुः साक्षाद्धर्मस्य लक्षणम्॥

Vedah Smritah Sadaachaarah Svasyacha priyam aatmanah,Etad chaturvidham praahuh saakshaat Dharmasy a lakshanam/

(The four corner-stones of Dharma are Veda, Smriti, Sadaachaara and above all, one's own Inner Conscience.)

2. Karma: good/bad forces created by one's actions. Work done with the least selfish motive frees us to forge another chain (Anonymous, 2022s) (Figure32).

सर्वे कर्मवशा वयम् ।
सब कर्म के ही अधीन हैं।

We all are under karma.

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अवश्यकरणीय च मा त्वां कालोऽत्यागदयम ।
जो कर्म अवश्य करना है, उसे कर डालो, समय बीत ना जाये ।

Do whatever you have to do, don't waste time.

Vanpary Mahabharat 158.216 | store.com

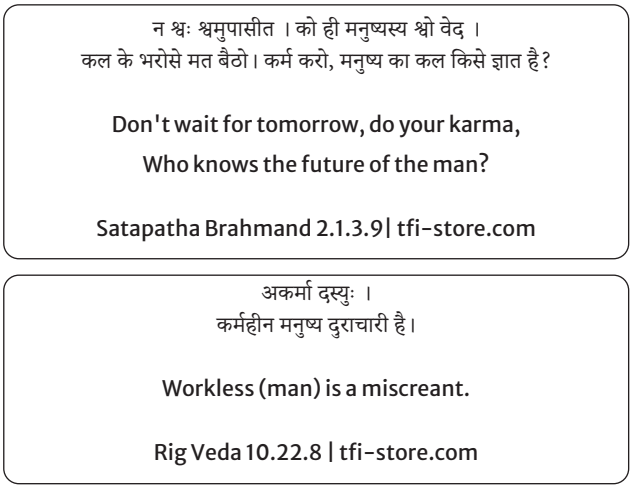


Figure 32: **Hindu Beliefs on Karma through the Sanskrit Shloka from Ancient Scriptures (Anonymous, 2022s)**

Belief in the existence of Soul (Atma)

This is the most important belief of Hinduism which states that each living creature on this planet has a soul, and all these souls are part of a Supreme Soul (Parmatma). Each and every creation in the universe has a soul. The ultimate aim of human life should be a part of the one with the Supreme Soul, which is Parmatma (Anonymous, 2022t).

Parents, teachers, and food are next to god

Hindus believe that parents, teachers (gurus), and food are next to God. They perform different functions, and all are important for our existence. Parents give us birth, nurture us, and teach us values. Teachers provide us with the knowledge to survive in this world. Food provides us the necessary energy to do our karma. Hence, parents, teachers, and food have the utmost importance and reverence in Hinduism (Anonymous, 2022t).

The World is an illusion

Hindus believe that this world is an illusion. What we see is not real. The best example is the colour of the sky. The sky appears blue to our eyes, but actually, it is not. In the same way, this world is different from what it appears to us (Anonymous, 2022t).

7.8.2 Awareness about soils through belief systems

Awareness about soil as a very important natural resource for humans has noticeably increased in the last few decades. Many actions and initiatives to promote soil governance for sustainable soil management and soil security are examples of such steps undertaken by several national and international institutions in many countries. There is now an increased awareness of soil at many levels for which many soil-related technologies are being adopted. However, the pace with which work should progress is not happening due to scarce consideration at management and policy levels. To increase and spread the awareness of the soil all over the world many steps and forums are in place (Table 10) (Towers et al., 2010; Harrison et al., 2005).

Table 10: A list of most known organizations and/or initiatives planned in the last decade to raise awareness and understanding of the importance of the soil (Source: Dazzi and Papa, 2022)

Web page
http://www.fao.org/global-soil-partnership/en/
https://esdac.jrc.ec.europa.eu/event/european-network-soilawareness-ensa
https://www.iuss.org/
https://www.un.org/en/observances/world-soil-day
https://www.4p1000.org/
https://www.globalsoilbiodiversity.org/
http://saveoursoils.com/
https://alpinesoils.eu/soil-awareness/
http://www.soilconservation.eu/
http://www.waswac.org.cn/waswac/index.htm
https://www.un.org/sustainabledevelopment/sustainabledevelopment-goals/
https://www.unccd.int/
https://www.unep.org/
https://www.ipbes.net/
https://www.sciencedaily.com/news/plants_animals/soil_types/
http://www.soil-net.com/
https://www.hutton.ac.uk/learning/dirt-doctor
https://www.museum-am-schoelerberg.de/
http://fondazionemida.com/museo-del-suolo

7.9 Sustainable practices of agriculture in Jainism

Agriculture, soil, and related sustainable practices for all religions centre around the generally accepted belief systems of the followers. The core philosophy of Jainism is non-violence. The Jain community, therefore, follows a vegetarian diet. Staunch Jains may even avoid vegetables growing underground and many animal-derived foods such as honey or dairy products.

Vegetarianism, as a matter of fact, is often an object of asserting social and traditional identity for Jains (Anonymous, 2022u). In Jainism food does not have any ritual significance and is considered merely as the physical materials needed to sustain one's own body.

Jain ascetics depend on Jain laypeople who again depend on the non-Jains. Since Jain ascetics are advised not to ask for anything, including food, the Jain laity[31] is expected to offer food to ascetics on their own. The laities are advised to the strict codes of food preparation, its distribution, and related behaviour. The violence in the act of cooking and its mild consequence is shifted from the ascetic to the layperson, and more specifically to the women who cook the food. Similarly, the Jain laity is not expected to pursue agriculture, and the slight consequence of the violence of tilling soil or harvesting produce is shifted to non-Jain peasants (Anonymous, 2022u). Literature suggests, however, that it is a misconception that agriculture is not permitted in Jainism. Jainism expressly mentions 15 types of highly sinful activities (karmadaan) that entail an enormous amount of himsa (violence) of Tras Jivas (two-sense to five-sense living beings) and should not be taken up by Jain shrawaks[32] except agriculture. A farmer works in the field to feed us. His activity cannot be called sinful (Anonymous, 2022v).

7.10 Sustainable practices of agriculture in Buddhism

For morality in agriculture and effective environmental care, Buddhism offers great teaching (Figure 33). Conservation of nature, including agriculture and landscapes, suggests the deeper spiritual meaning of caring for all things in the world (Falvey, 2005).

[31] Jain laity: ordinary people, as distinct from professionals or experts.

[32] Jain shrawaks (practitioners of the twelve vows): They are householders and therefore their participation in the management of the society or state becomes essential.

The Buddha and the Farmer

I sow faith as the seeds. My discipline is the rain. My wisdom is my yoke and plough. My modesty is the plough-head. The mind is the rope. Mindfulness is the ploughshare and the goad. I am restrained in deeds, words and food. I do my weeding with truthfulness. The bliss I get is my freedom from suffering. With perseverance, I bear my yoke until I come to nirvana. Thus, I have done my ploughing. It brings the fruit of immortality. By ploughing like this, one escapes all suffering.

-------Lord Buddha

Source: https://www.buddhanet.net/e-learning/buddhism/lifebuddha/2_8lbud.htm

Figure 33: Lord Buddha's teaching for a farmer

Buddhist traditions are less concerned about the food materials than the way these are consumed. The reason is that dukkha (suffering/sorrow) is rooted in our cravings in different ways and food is the second most popular example of human craving (Anonymous, 2022w). Buddhist Global Relief (Anonymous, 2022x), as a matter of fact, has taken up several projects across the world for sustainable agriculture. Buddhist scripture informs about the ritual practice of thaumaturgic (magical) weather control for thriving agriculture through overpowering mythical Nagas. Traditionally, these serpentine beings are held responsible for the amount of rainfall (Hidas, 2019).

7.11 Sustainable practices of agriculture in Sikhism

Sikhism advises harnessing nature and not to abuse or dominate it. The tenth Guru founded the Order of the Khalsa in 1699, which practises the spiritual discipline of Sikhism, and is committed to preserve the global society. Sikhism is the youngest of the world's great monotheistic religions. Punjab soils are very fertile and since the dawn of time perfectly landscaped for agriculture. It was a kind of entrance gate, through which representatives of different ethnic and religious groups entered India, creating the cultural mosaic, in which sharp differences between different communities blurred.

Sikhs are traditionally attached to land and agriculture; 66% of the population of Sikhs in Indian Punjab live in non-urbanized areas. Approximately 70% of all traditional cereals (except for rice) in India are produced in Indian Punjab and Haryana (Ghuman, 2012). According to the Sikh scripture (the Siri Guru Granth

Sahib) the purpose of human beings is to achieve a blissful state and to be in harmony with the earth and all of god's creation (Figure 34) (Anonymous, 2022j)

The purpose of human beings is to achieve a blissful state and to be in harmony with the earth and all of God's creation.

-------Siri Guru Granth Sahib Ji (Ang 723)

Figure 34: The Siri Guru Granth Sahib declares in the Sikh scripture

8. Soil management during various Hindu civilizations

8.1 Background

Since soils were used mostly for agriculture, therefore, it was managed from that point of view to produce more food for new human civilization and the formation of new colonies in different areas. In India, such a system of colonization spans nearly half-a-million years and this period has two segments, namely the prehistoric (before writing started) and the historic (after initiation of writing). The prehistoric period is divided into the stone, bronze, and iron ages. Agriculture led to the emergence of villages, and towns were formed and gradually developed owing to agriculture. And later, it brought different occupational groups in society. The first urbanization occurred during the bronze age in the arid and semi-arid region of north-west India in the valleys of the Indus and the Saraswati rivers (now dry Ghaggar–Hakra bed). The Indus or Harappan civilization represent the urbanization during 3500–1500 B.C. The rest of India during this period was inhabited by neolithic and chalcolithic farmers and Mesolithic hunter-gatherers (Misra, 2001). The soil management needed the help of implements to till the land for cultivation. It required good soils as well as the proximity of water both for human and agricultural use, justifying foundation of the most of the civilizations near the perennial rivers.

Agriculture came into being nearly about 8000 years ago. And in its wake came massive changes in various spheres of life in society, encompassing economy, technology, and demography. The people with hunting professions in the hills and forested places had enough forest produce for consumption and to maintain human life. These people migrated to the plains when agriculture was introduced with ample food and water. Iron technology (~ 3000 years ago) shifted the agricultural focus to the eastern part of the Ganga valley. As a matter of fact, the epic Mahabharat (beginning of the first millennium BCE) location represents

the Indo-Gangetic divide and the upper Ganga-Yamuna doab (land between two rivers). Iron technology enabled pioneering farmers to clear the dense and tangled forests of the middle and lower Ganga plains. The focus of development now shifted further eastward to eastern Uttar Pradesh and western Bihar which witnessed the events of the Ramayan epic and the rise of the first political entities known as Mahajanapadas as also of Buddhism and Jainism (Misra, 2001).

8.2 Vedic agricultural system: Modern agronomy

Vedic agricultural system was enriched as supported by the numerous references to various stages of cultivation (such as ploughing, sowing, harvesting, threshing, and preparing agrarian produce), which indicates the rich tradition of farming in ancient India (Also see section 7.1. of this chapter). Vedic literature narrates developed agronomy since different types of farmers used agricultural implements for other crops. Two Vedic terms of farmers karsivana and kinasa, the linguistic basis of the last word Kisana, remind us of the motto of the Indian agricultural society, Jai Jawan Jai Kisan (Chattopadhyay, 2007). The Satapatha Brahmaṇa[33] suggested four important stages of agricultural crop-production such as karsana (tilling/ploughing a land), vapana (sowing of seeds), and lavana (reaping/harvesting crops), and, mardana (threshing to get the grains) (Chattopadhyay, 2007). Modern agronomic practices resemble those present during the Vedic era. Depending on priority, different types of fields for different crops [brihi (rice), yava (barley), masa (maize), mudga (mung bean), priyangu (medicinal herb), anu (fine rice), syamaka (Indian barnyard millet), nivara (medicinal rice), godhuma (wheat) and masura (lentil)] were prepared.

As food is the basic need of human beings, a developed agricultural system appeared essential. Vedic seers have also given top priority to soil and crop management (Agronomy). Three types of cornfields [urvara (fertile), irina and sasypa] were mentioned; besides, corn from cultivable land (krstipacya) and uncultivable land were also found in the literature. Priority on irrigation, different types of food production, use of different fertilizers, and various agricultural implements give us an idea of advanced agronomy at that time (Chattopadhyay, 2007).

Food (anna) being an essential requirement of human beings, the production of food became the primary concern in agriculture. Traditional agriculture remained the main stay in India, with about 67% of its total population

[33]Satapatha Brahmaṇa: It means 'Brāhmaṇa (commentaries on the Vedas) of one hundred paths of the Vedic sage Yajnavalkya. It contains detailed explanations of Vedic sacrificial rituals, symbolism, and mythology

engaged in farming for their livelihood. Since agriculture depends on fertile soils to boost the rural economy, soils/lands management was considered essential. India has sufficient fertile land (urvasā kṣetra), well irrigated by rivers to provide food for every living being of this country. It is imperative that India needs to keep pace with modern agricultural technology and also follow the traditional wisdom of maintaining soil and nature for sustenance.

Two entire Vedic hymns on agriculture (Rig Veda IV.57 and Atharva Veda III.17) and more than two hundred Vedic references on land farming, different agricultural implements, irrigation, farmers, fertilizers, and crops are sufficient to get a clear idea of the Vedic agrarian system. The Rig Veda (X.34.13) advises that land farming is the best means of gaining wealth. According to the Atharva Veda (VII.10.24) king Pṛthu Vainya, a scion of Vaivasvata Manu invented cultivation and produced crops. People used to take these crops as a means of living, and cultivation was accepted as the best rural profession.

(tāṃ pṛthīm vainyodhok tāṃ kṛṣiṃ ca sasyaṃ cādhok, te kṛṣiṃ ca sasyaṃ ca manuṣyā upajivanti, kṛṣṭarādhirupajīvanīyo bhavan). Aśvins are also treated as cultivator with the sowing of barley grain in the tilled fields by means of a plough (yavaṃ vṛkeṇāśvinā vapanteśam;yavaṃ vṛkeṇa karṣathaḥ).

According to the Yajur Veda, land or agricultural field is the primary need for cultivation, and it is the best place for sowing seed (***kiṃ vāvapanaṃ mahat, bhūmir āvapanaṃ mahar***) and one should produce good crops (***susasyāḥ kṛṣiskṛdhī***). In the Vedic period, the duty of a king was also to look after the progress of agriculture (***kṛṣyai tvākṣemāya tvār ayyai tvāpoṣāya tvā***). The Taittiriya Saṃhitā also records the importance of cultivation and suggests cultivating properly for yielding good crops (***kṛṣyai tvā susasyāyai: annaṃ kṛṣir vṛṣṭir vaṣaṭ svāhā***). The ***Atharva Veda*** (III.17) gives importance to ***kṛṣi*** (agriculture), and for producing a good harvest, it records a prayer to king Bhaga to let the ploughing to deep down the soil (***bhago no rājā ni kṛṣiṃ tanotu***). The ***Kāṭhaka Saṃhitā*** also prescribes deep ploughing for the rich production of paddy and barley (***adho dūraṃ khaned adho vā asyā*** (***pṛthivyāḥ***) ***vīryam, viryasyābhikirptyai tasmāt sukṛṣṭe vrīhiyavā pacyante…tadimā prajā upajīvanti***). But according to modern agriculturists, deep ploughing is suggested for selected crops only. The same text also suggests producing rich crops from agriculture (***kṛṣiṃ susasyām utkṛdhi***).

Rain is essential for agriculture. Cloud is praised as a personified deity (***tak kṛṣiḥ parjanyo devatā***). Agriculture depends not only on water but also on all five primal elements. For the production of crops, all these ***pañchmahābhūtas*** are essential in different forms. Earth/ land/soil is the primary need for sowing

seeds. Water supplies the essential sap (for growing the plants) through rainfall or irrigation from rivers. Without heat (***tejas***) growth is impossible. Air (***vāyu***) is essential for fertility. Maruts are praised as grinders of soil (***pipiṣvatī***). Without space, crops cannot take shape. So, agriculture depends on all natural phenomena. Hence, the ***Śatpatha Brāmaṇa*** suggests ***sarvade vatyā vai kṛṣiḥ***.

To denote the agricultural field or cornfield, the term ***kṣetra*** is mainly used in the Vedic literature. The lord of the field ***Kṣetrasyapati*** makes the presiding deity of the field, praised in the Vedas for good crops. Agricultural lands vary in terms of quality and produce as mentioned in the Vedas such as cornfield full of ripened corns (***pakvam kṣetrāt kāmadughā ma eṣā***), barren land, pasture land (***agavyūti kṣetram, khila*** or ***khilyā***), wasteland (***khile gā viṣṭhitā iva***) ***urvarā*** or fertile land (***apnavatīṣu urvarāsn iṣṭanī***). Indra possesses thousands of fertile lands (***taṃnaḥsahasrabhara-murvarāsānī***). If soils are subjected to a blazing fire, the fertile or productive land may be converted into waste or uncultivable land (***uta khilyāurvarāṇāṃbhavantī***).

In the Vedas, ploughing is considered as an auspicious mark of happiness, indicating prosperity.

Śuna (prosperity or happiness) and ***sīra*** (plough) are two deified objects related to agriculture (***śunāsīrāvimāṃ vācaṃ juṣethām***). The following two mantras depict a real picture of tilling the land with the bullocks by a happy farmer:

शुनंवाहाः शुनंकृतस्तुलाङ्गलम् शुनंवरत्रा बध्यन्तां शुनमष्ट्रा मुदिङ्गयः।

śunaṃvāhāḥ śunaṃkṛṣatulāṅalam śunaṃvaratrā badhyantāṃ
śunaṃaṣṭrā mudiṅgayaḥ.

All the agricultural objects like plough, ox, ploughman, the binding rope, and the goad are the mark of prosperity. Again, as a symbol of prosperity, ***śuna*** and ***sira*** are conjointly appreciated:

शुनंनः फल विकृषन्तु भूमिं
शुनं कीनाशा अभियन्तु वाहैः।
शुनं पर्जन्यो मधुना पयोभिः
शुनाशीराः अस्मासु धत्ते।

śunaṃnaḥphāla vi kṛṣantubhūmiṃ
śunaṃkīnāśāabhiyantuvāhaiḥ
śunaṃparjanyomadhunāpayobhiḥ
śunāśīrāasmāsudhattem.

Here we find that the ploughman is tilling the land happily with the sharpened ploughshares and praying to the cloud for sufficient rain. The Atharva Veda records a beautiful mantra describing a well-shaped, lance-pointed and sharpened plough with a handle (***lāṅgalaṃpavīravaisuśīmaṃsomasatsaru***).

Mainly two agricultural seasons are noticed in the Vedas, such as Kharif (July to October) and Ravi (November to March/April) (***dviḥsaṃvatsarasyas-asyaṃpacate***). Generally, most agricultural crops ripen after three months, and so in a year there could be four crops, as mentioned in the ***Taittiriya Saṃhitā*** (***yavaṃgrīṣmāyaauṣadhīrvarṣābhyovrīhiñcharademāṣatilauhemantaśiśirābhyām***). These are the time of ripening crops like barely for summer, medicinal herbs for the rainy season, paddy in autumn, and beans and sesamum in winter. According to the ***Kauṣītaki Brāhmaṇa***, after one day of ***chaitra amāvasyā*** (i.e.,***chaitra śuklapratipadā***), the winter crops are ready for harvesting (***chaitrasyāmāvasyāyāekāhaupriṣṭād-dikṣerannāgataṃsasyaṃbhavatr***).

Agricultural implements are also mentioned in the old literature. Modern agricultural implements are not comparable with the ancient tools; yet, the old and rough implements like the wooden plough with a sharpened ploughshare for tilling the agricultural land with bullocks are still the base of the rural economy. To indicate a plough, the terms used in the Vedas include ***lāṅgala, sīra, phāla*** and ***stega*** denote ploughshare, which actually tills the soil. The term ***iśa*** suggests the plough-stilt or the long wooden stick connected with the plough; yuga is a yoke, and ***varatrā*** means a rope for binding the bulls with the yoke and plough. The handle of a plough is called ***traru*** in the Vedas. For controlling the yoked oxen, two implements are used – ***aṣṭrā*** and ***tottra*** to denote a goad. ***Sṛni*** and ***dātra*** (sickle) are used for reaping the harvest (lavana). Khanitra (shovel) is also used in the Vedas for digging the soil. The Vedas record the use of śūrpa for winnowing the corn like paddy and barley and titau for clearing the flour made of barley (***saktumivatitaunāpunantaḥ***). The two terms sīra and laya are used simultaneously for two functions (furrowing and harrowing a field), respectively (***sīrañca me layaśca me***).

Vedas mentioned irrigation, fertilizers, and prevention from natural calamities. Though agriculture mainly depends on adequate rainfall (***kṛṣiśca me vṛṣṭiścame***) as a substitute, the Vedic farmers take the help of human-made irrigation systems for irrigation. Rigveda (VII.49.2) describes four types of irrigated water. These are (1) from rain (***divyāḥ***), (2) from well (***khanirtimā***), natural (***svayaṃjāḥ***), and (4) from those rivers which are mixed with the sea (***samudrārthāḥ***). Artificial irrigation is also mentioned and this is referred to as '***khanitrimā āpaḥ***' meaning irrigation from a well and hardaṃ kuly for irrigation from a canal.

For icreasing the yielding capacity of soils, manures or fertilizers are also used in the agricultural field. Mostly cow dung used as manure is known to the Vedic seers as ***karīṣa, śakan***, and ***śakṛt***. They knew that the use of adequate cow dung in agricultural fields results in a rich harvest (***karīṣinīṃ phalavatīṃ svadhām, nityapuṣṭāṃ karīṣiṇīm***).

Vedic seers were also conscious of the controlling method of natural calamities. The Atharva Veda mentions about the plant-damaging evils (like moles, rats, birds, insects, excessive rain, and drought) which could be prevented by some spells (***hataṃ tardaṃ samaṅkam ākhum aśvinā chintam tarda hai, pataṅga hai jabhya hā upakvasa***).

In crop production, harvesting is an important job. If the farmer cannot collect the ripened corn in time, he has to face a severe loss. The farmers plough the fields and scatter the good seed on fertile land, which is fed and watered by natural phenomena, but the ripened corn is cut or reaped by farmers with cutters like a sickle as mentioned in the following mantra of Rig Veda:

युनक्तुसीर वि युग तनुध्वं कृतयोनौ।
वपतेह बीजं, गिरा च श्रुष्टिः सभराः असन्नो।
नेदीयैत्सण्ज्यः पक्वमेयात्।

Yunaktusīra vi yuga tanudhvamkṛtayonau
Vapatehabījam, girā ca śruṣṭiḥsabharāasanno
Nedīyaitsṇyaḥpakvameyāt.

[After reaping the ripened corn, they bound into bundles and
beaten out or threshed onto the
floor of the granary (khale na parṣān prati hanmi].

In agriculture, a farmer gets happiness when he finds the production from three types of cornfields – ***urvarā*** (fertile), ***iriṇa*** (barren land), and ***śaspya*** (marshy land). The Yajur Veda mentioned twelve types of food grains in the following mantra:

ब्रीहयश्च मे, ययाश्च मे, माषाश्च मे, तिलाश्च मे,
मुद्गाश्च मे, खल्वाश्च मे, प्रियङ्गवश्च मे,
अणवश्च मे, श्यामाकाश्च मे, नीवाराश्च मे,
गोधूमाश्च मे, यज्ञेन कल्पन्ताम्।

Brīhayaśca me, yayāśca me, māṣścame, tilāśca
Me, mudgāśca me, khalvāśca me, priyaṅgavaśca
Me, aṇavaśca me, śyāmākāśca me, nīvārāśca me,
Godhūnāśca me, yajñenakalpantām.

These twelve corns are ***vrīhi*** (paddy), ***yava*** (barley), ***māsa*** (a kind of bean, Phaseolus rediatus), ***tila*** (sesamum), ***mudga*** (a kind of bean, Phaseolus mungo), ***Khalva*** (chick-pea or pulses, ***canake***), ***priyaṅgu*** (panic seed, Panicum ***italicum***), ***aṇu*** (millet, ***Panicum niliaceum***), ***śyāmāka*** (a variety of millet, ***Panicum frumentaceum***), ***nīvāra*** (wild rice), ***godhūma*** (wheat), and ***masūra*** (lentil, ***Ervum hirsutum***).

It is very interesting to note that most of these cultivated grains are known as ***dhānya*** in the ***Brihadaranayaka*** Upanishad as all these grains are essential for sustaining life. According to this Upanishad, there are ten cultivated grains such as rice, barley, sesamum, beans, millet, panic seeds, wheat, lentils, pulses, and vetches (***Dolichos biflorus Linn***) (***daśa grāmyāṇi dhānyāni bhavanti, vrīhiyavāstilamāṣā aṇupriyaṅgavo godhūmāśca masūrāśca khalvāśca khalakulāśca***).

In the Vedic period, the knowledge of food grains preservation in granaries was available. The Vedas mention khala as the threshing floor and ***khalapā*** as the bamboo-made granary. The terms – ***ūrdara, sthivi***, and ***kṛdara*** are used in the Vedas in the sense of granary or treasure house. For example, ***tām ūudaraṃ na pṛṇatā yavena*** means a granary filled with barley, ***nirgā ūpe yavarn iva sthivibhyaḥ*** means men bring barley from granaries: and, ***samiddho añjan kṛdaraṃ matīnām*** suggests decking the treasure house or prayers.

Vedic agricultural system formed the base of the rural economy because the rural people could maintain their livelihood by engaging themselves in different types of agricultural work. The advancement of any field work depends on long experience. Hence, the Vedic agricultural system is the pioneer of the modern agricultural design in India to provide adequate food to each person in this country.

8.3 Soil management and agriculture during the Indus Valley Civilisation

8.3.1 Indus Valley Civilization

The Indus Valley Civilization represents the Bronze Age civilization in the north-western regions of South Asia, lasting from 3300 BCE to 1300 BCE, and in its mature form from 2600 BCE to 1900 BCE (https://en.wikipedia.org/wiki/Indus_Valley_Civilization) (Figure 35a).

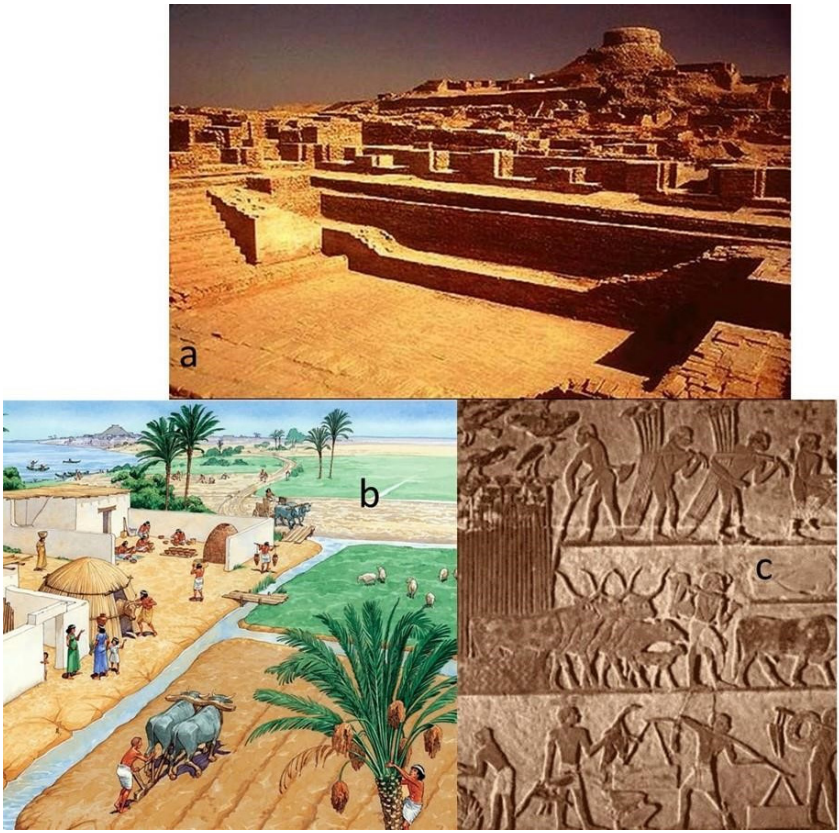


Figure 35: (a) Indus Valley Civilization (IVC) site; (b) agriculture in IVC; and (c) agriculture and implements in IVC

The cities of the ancient Indus were characterized by neat urban planning, brick-built houses, adequate drainage and water supply systems, and different techniques showing excellence in handicrafts and metallurgy. The Indus civilization

(also known as the Harappan civilization), was first excavated early in the 20th century in what was then the Punjab province of British India and is now Punjab, Pakistan. The discovery of Harappa and, soon afterwards Mohenjo-Daro was the culmination of work that had begun after the founding of the Archaeological Survey of India in the British Raj in 1861. Mohenjo-Daro and Harappa accommodated 30,000 and 60,000 individuals, and the civilization may have contained between one and five million individuals during its peak. This civilization halted and later shifted further to the east due to water shortage, causing migration of its population during the 3rd millennium BCE.

8.3.2 Soil management and agriculture

Archaeological and geographical evidences suggest that the neolithic farming was spread from the near east into north-west India, and there was local domestication of barley and the zebu cattle at Mehrgarh (Gangal et al., 2014). Farming had an independent local origin and food production was an indigenous South Asian phenomenon. People used domesticated wheat and barley. Neolithic domesticated crops in Mehrgarh include more than 90% barley (Gangal et al.,2014). The cattle portrayed on Indus seals are humped Indian aurochs similar to Zebu cattle. Indus population was among the earliest people to adopt complex multi-cropping strategies across both seasons [summer food (rice, millets, and beans) and winter food (wheat, barley, and pulses)], using two different irrigation strategies. Pieces of evidence suggest a separate domestication process of rice in ancient South Asia, based on the wild species Oryza nivara (Bates et al., 2016). This paved the way for the concept of wetland and dryland agriculture of local (Oryza sativa indica) rice before the truly wetland rice (Oryza sativa japonica) around 2000 BCE.

The Indus people developed an irrigation system for the crops. It permitted them to produce crops according to their requirements by neglecting traditional nomadic ways and using modern techniques to satisfy the city's requirements. Agriculture was very important to the Indus people trading and agriculture were the only two modes of their survival. Those who could not trade engaged themselves in farming and agriculture. It was one of the prime reasons why the Indus valley civilization survived for a long time. Agriculture in the Indus valley was primarily dependent on both soil quality and improved farming techniques (Figure 35b). Major crops include winter food items (wheat, barley, peas, lentils, linseed, and mustard seeds) and summer food materials (millet, sesame and rice). Modern techniques in field and also improved transport system flourished among the Indus people (Figure 35c). Foods, materials, and other agricultural goods were also a part of the trade.

Indus valley civilization had a dominant meat diet of cattle, buffalo, goats, pigs, and chickens (https://en.wikipedia.org/wiki/Indus_Valley_Civilization). Remnants of dairy products were also discovered. Seven food balls (laddus) were found in an intact form, likely composed of legumes, primarily mung and cereals.

9. Soil/agriculture management during various dynasties

Out of approximately 170 different dynasties found in the literature, thirty-three (33) existed before the Christian Era (BCE), hundred and twenty (120) during the Christian Era (CE), and fifteen (15) dynasties ruled in both BCE and CE. For brevity, a few dynasties ruling before the Christian Era (BCE), namely, Kuru, Panchala, Kosala, Haryanka, Anuradhapura, Nanda, Mauryan, Shishunaga, and Kanva are discussed here. The dynasties ruling during the Christian Era (BCE), namely the Pallavas, Chalukyas, Kamarupa, and Marathas, are discussed. Similarly, brief discussions are made for the Chera, Chola, Pandya and Satavahana dynasties ruling during both BCE and CE. These dynasties were selected to cover the geography, number of years of ruling, name and fame for their kings in maintaining their kingdom keeping in view of preserving Vedic civilizations of respecting Mother Earth/soil. The following paragraphs discuss the important achievements of these dynasties; their contributions, linked with preserving soil and its fertility, are detailed later.

9.1 Agriculture in Hindu dynasty/ kingdom Before Christian Era (BCE)

During the Holocene[34] , it was necessary to domesticate plants and animals for the expansion of establishments and to feed the increased population. This also necessitated human beings from hunting to selective hunting and finally to herding. Throughout the world this happened over the past 10,000 years (Simmons 1989). Domestication of crops (wheat, barley, jujube) and animals (sheep, goat) is recorded in the Indian subcontinent during 9000 BCE (Simmons,1989; Allchin and Allchin, 1987). In India, plants and animals were always a part of worship. For instance, pipal (Ficus religiosa) and banyan (Ficus benghalensis) are the oldest trees worshipped in India since ancient times (Gupta, 2004). Specific mentions of soil and its management in Hindu dynasties are few and far between. There is scanty literature about the Hindu dynasty and agriculture, although an attempt is made to briefly mention various Hindu dynasties and the subject of agriculture in the following paragraphs.

[34]Holocene: The Holocene is the current geological epoch. It began approximately 11,650 cal years before present (BP) (c. 9700 BCE), after the Last Glacial Period, which concluded with the Holocene glacial retreat.

There are several Hindu dynasties mentioned in the literature. For brevity, a few are discussed from the lists of dynasties/kingdoms present Before Christian Era (BCE), after Christian Era (CE), and in the transition of both (Figures 36, 37, and 38).

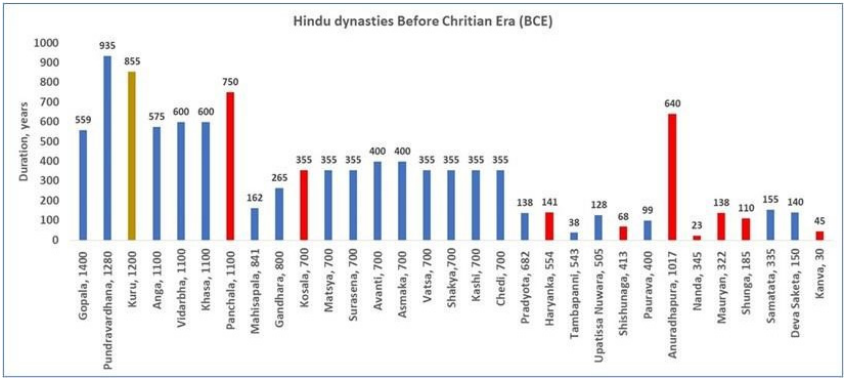


Figure 36: Hindu Dynasties and their duration before the Christian Era (BCE) (Figures after the text in the horizontal axis indicate the beginning of the Dynasties)
(Source: https://en.wikipedia.org/wiki/List_of_Hindu_empires_and_dynasties)

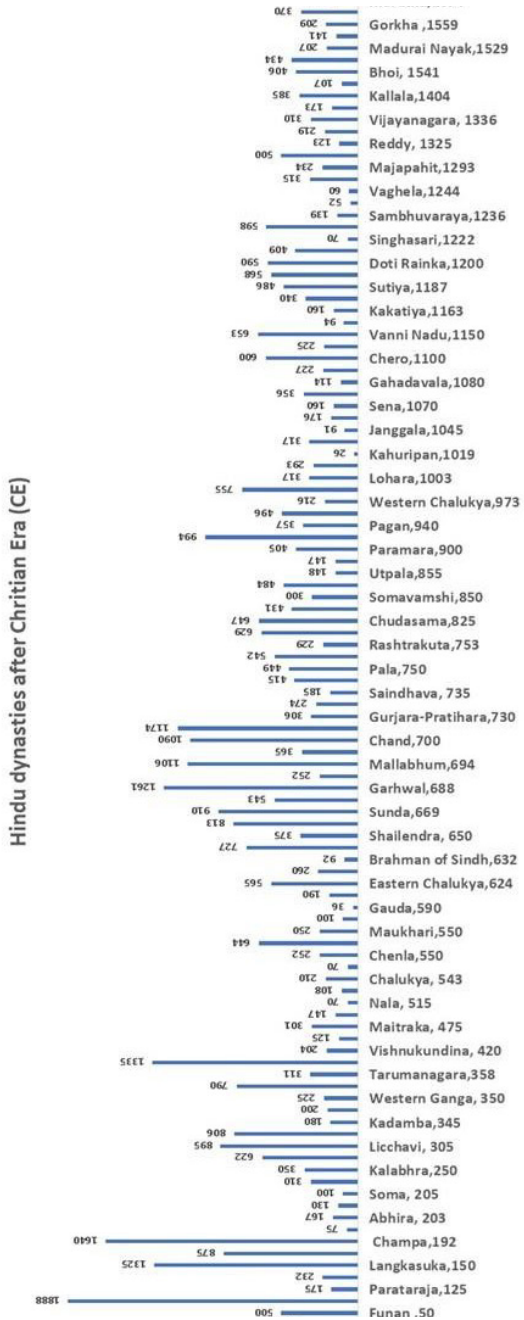


Figure 37: Hindu Dynasties and their duration after the Christian Era (CE) (Figures after the text on the horizontal axis indicate the beginning of the Dynasties)
(Source: https://en.wikipedia.org/wiki/List_of_Hindu_empires_and_dynasties)

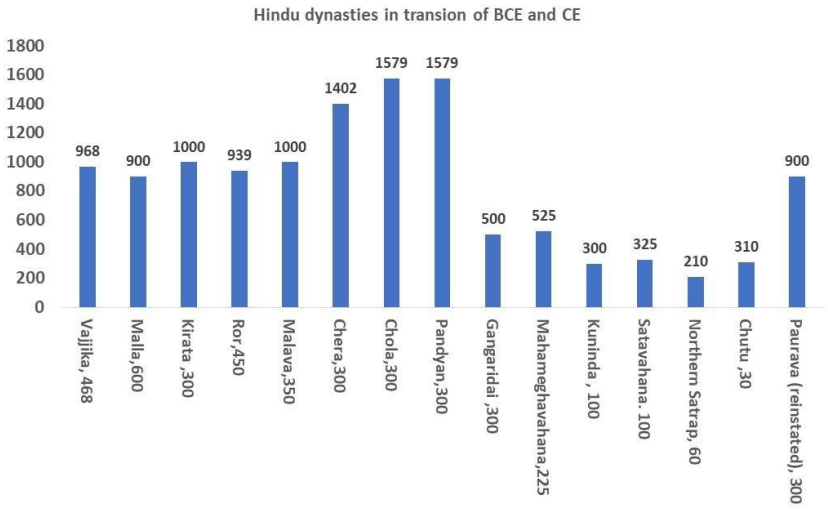


Figure 38: Hindu Dynasties and their duration in the transition before (BCE) and after the Christian Era (CE) (Figures after the text in the horizontal axis indicate the beginning of the Dynasties) (Source: https://en.wikipedia.org/wiki/List_of_Hindu_empires_and_dynasties)

9.1.1 The Kuru kingdom (1200 – 345 BCE)

Kuru (Sanskrit: Kuru) kingdom encompassed the northern part of India [Delhi, Haryana, Punjab, Uttar Pradesh (western)]. After the era of the Rig Veda, this dynasty was a prominent one. The tribes that consolidated during this era were largely semi-nomadic and pastoral tribes. When the settlement was shifted near the Ganges, farming prospered mainly with rice and barley. Vedic literature of this period indicates the growth of surplus production and the emergence of specialized artisans and craftsmen.

9.1.2 The Panchala kingdom (1100-350 BCE)

The Panchala kingdom was one of the historical Mahajanapadas of ancient India (c. 30th to 4th centuries BC). The Panchala kingdom (The Mahabharat fame) extended from the Himalayas in the north and the Naimisha Forest to the east. Panchala, the ancient kingdom of northern India, was founded in the Ganges-Yamuna Doab of the Upper Gangetic plain. Closely allied with the Kuru Kingdom, the Panchalas were mighty states in those days (c. 1100–500 BCE) (Figure 39).

Figure 39: The Panchala Kingdom in the Mahabharata:

In the present day the city of the Panchala kingdom is located at the Ganges, Yamuna plain surrounding Uttarakhand and western Uttar Pradesh. During the Vedic period, the kingdom was the centre of Vedic civilization and political developments. According to the Mahabharat stories, Draupadi, the daughter of king Drupada was married to the Pandavas. The same Panchala kingdom mentioned in the Buddhist text was one of the sixteen Mahajanapadas of the 6th century BCE. Mahapadma Nanda ruled this city in the mid-4th century BCE. Later the Kingdom was annexed into the Magadha Empire (Anonymous, 2022z).

9.1.3 Anuradhapura dynasty/kingdom (1017- 377 BCE)

The agricultural landscape finds significance in Anuradhapura consisting of large water tanks, paddy fields, and canal systems which are still sustained in the modern era. During the middle stone age, Sri Lanka was connected to the southern part of India (Dereniyagala, 1992). It is assumed that pre-historic people from India walked through the sea, by the stretch of land, and entered Sri Lanka. Excavations showed evidence of various technologies related to agriculture (iron technology, breeding of horses and cattle, paddy cultivation, and wheel-made clay pottery of high quality, stone tombs, and wattle and daub structures) at this site (De Silva, 2019). Agriculture with rice cultivation using irrigation before 800 BCE has been reported in the northern areas. The ploughing ceremony, as an important ritual relates well with agriculture and human settlements in this area (Sahasrabudhe and Kashyap, 2016). These rituals symbolize a performative process for human settlements and the relation between the sacred place of Lord Buddha and the monasteries (Figure 40). The Buddhist holy site of Anuradhapura represents the great stupas, symbolized by sustainable agriculture using irrigation in those days

Figure 40: Centre – stupas and monasteries, and periphery – water and cultivation. (Source: De Silva, 2019)

9.1.4 The Mauryan empire (322-184 BCE)

The Mauryan state took great care to promote agriculture. Categorizations of soils, use of meteorological observations, and using water from a dam near Girnar river (known as Sudarshana tadaga (water-tank) (Saurashtra, Gujarat) for agricultural use were features of the Mauryan empire. Horse-drawn chariots were made to better the traditional bullock carts for quicker service (Anonymous, 2022aa). The settlement of permanent villages through the process of janapadanivesha helped the sustenance of agriculture to ease human life. Farmers were encouraged to cultivate fallow lands (Figure 41). The Mauryan army brought peace to the cultivable areas and kept the areas safe from miscreants. Many waterways and roads were built for better communication and transport.

Figure 41: Agriculture in the Mauryan Empire (Source: Anonymous, 2022ab)

Agriculture was a priority during this time. The facility of irrigation was provided by the state and there were rules for the benefit of agriculturists. Landowners were more respected than landless people. The crops grown included rice, kodrava (coarse grain), millet, sesamum, varieties of pulses, wheat, barley, linseed, mustard, sunflower, sugarcane, vegetables, tubers, and fruits like gourds, plantain, pumpkin, and grape. There is also a mention of the husbandry of livestock (cows, buffaloes, goats, and sheep). Poultry, even camels, asses, dogs, and pigs

were also part of the animals reared. Megasthenes (300 BCE), in his book, provides an eyewitness account of Indian agriculture at that time.

"India has many huge mountains which abound in fruit trees of every kind and many vast plains of great fertility. The greater part of the soil is under irrigation and consequently bears two crops in the course of the year. In addition to cereals, there grows millet and different sorts of pulse and rice throughout India. Since there are two monsoons in the course of each year the inhabitants gather in two harvests annually."

9.1.5 The Kosala kingdom (700-345 BCE)

One of the ancient kingdoms in India, Kosala consisted of sixteen (16) Mahajanapadas[35]. Kosala city (second Mahajanapadas of the sixteen) was located in the north-west of the Maurya Empire and next to Kashi (Figure 42). There was a long battle between Kasi and Kosala, as described by the Jatakas[36]. Many kings ruled the city; among them Kansa was very daring and was given the unique title of Baranasiggaha, after his conquest of Kashi (Figure 43).

Figure 42: The Kosala Kingdom in Jataka Scriptures (Source: Anonymous, 2022ac)

[35]Mahajanapadas: The Mahajanapadas (Sanskrit: maha, great; janapada foothold of a people) were sixteen kingdoms or oligarchic republics (small groups of people controlling an area) that existed in ancient India from the sixth to fourth centuries.

[36]Jatakas (Pali and Sanskrit meaning birth) are any of the extremely popular stories of the former lives of the Lord Buddha, which are preserved in all branches of Buddhism.

Figure 43: The kingdom of Kosala after Bimbisara (Source: Anonymous, 2022ac)

9.1.6 The Haryanka kingdom (554-413 BCE)

The Haryanka dynasty, the third ruling dynasty of Magadha, succeeded the Pradyota dynasty and Barhadratha dynasty. Initially, the capital was Rajagriha, which was shifted to Pataliputra, near the present-day Patna (Bihar state) in India, during the reign of Udayin. According to the Buddhist text, the Mahavamsa, Bimbisara was anointed king by his father at the age of fifteen, and he was the founder of the Haryanka dynasty.

Agricultural production had gained an appreciable jump with the discovery and proliferation of iron tools during this time. This reduced the migration of people and encouraged them to settle and live a static life in a territory. These social and economic changes helped the emergence of Janapa, which stood for regions rich in resources, exceptionally favourable for carrying out agricultural activities. Paddy emerged as the pre-eminent crop, and the rich produce may have led to more rigid taxation initiated by the state.

9.1.7 Shishunaga dynasty (413-345 BCE)

The Shishunaga dynasty is believed to have been the second ruling dynasty of Magadha, an empire of ancient India. This dynasty was the second ruling dynasty of Magadha, succeeding Nagadashaka of the Haryanka dynasty. The Shishunaga destroyed the power of Avanti with its capital at Ujjain (Now in Madhya Pradesh, India) to bring peace to the region.

9.1.8 Nanda dynasty (345-322 BCE)

The Nanda dynasty expanded its empire to include a more significant part of northern India, using more centralised management. Nanda king has been mentioned in the Puranas as ekarat (single ruler), although others (the Greek) indicated the presence of a more federated system of governance. The Nanda dynasty ruled from Punjab in the west to Bengal in the east and the Vindya mountains in the south of India. The Nandas accumulated enormous resources using a new monetary system and taxation scheme. Ancient texts suggest dissatisfaction of the ordinary people due to oppression, taxation, and rudeness of the Dynasty. Later, Chandragupta Maurya, the founding member of the Maurya Dynasty, and Chanakya, his mentor, brought peace to the citizens by ousting the Nanda king.

Both the Mauryan and Nanda dynasty, as a part of the Magadh empire, was prosperous due to economic solvency. A large group of people was engaged in agriculture. The people cleared a portion of the forest to rehabilitate others with surplus food materials. Due to the geographical locations of land between the Son and the Ganges rivers, the soils were fertile to produce more food using multiple crops in a year. Due to soil fertility, land productivity brought huge prosperity to the people. The grains and other products were also transported easily due to the proximity of the perennial river Ganges. Besides, the mining of iron and other minerals helped make necessary equipment for tilling soils.

9.1.9 Kanva ynasty (75-30 BCE)

The Kanva dynasty ruled for a short period in the eastern and part of central India after the Shungas in Magadha. They were Brahmins and considered themselves descendants of Rishi Kanva. The whole dynasty, comprising four reigns, covers a period of only forty-five years. The literature indicates a disturbing time during this regime.

9.2 Hindu dynasties/kingdoms present during the Christian Era (CE)

9.2.1 The Pallava dynasties (275-897 CE)

The Pallavas were well-known for their strong soldiers and this is the reason for the upswing of the Pallava dynasty. They ruled for over 500 years. Pallava dynasty conquered the region of Thondaimandalam which was located at Pallava Puri. Pallava founded their kingdom in the ruins of the eastern part of the kingdom of the Satvahanas. After a disaster, the Pallavas moved to Kanchipuram and developed Kanchi (modern Kanchipuram near Chennai, India) as their capital. Kanchipuram is distinguished for its temples and Vedic learning. The Pallavas were the Dravidian country's emperors, and they quickly adopted Tamil culture. The Pallava dynasty was a South Indian dynasty that ruled a significant portion of the

Deccan, also known as Tondaimandalam. The dynasty rose to prominence after the downfall of the Satavahana dynasty, with whom they had formerly served as feudatories.

The Pallavas became a major Dravidian power during the reign of Mahendravarman I (600–630 CE) and Narasimhavarman I (630–668 CE), and dominated the southern Telugu Region and the northern parts of the Tamil region for about 600 years until the end of the 9th century. Throughout their reign, they remained in constant conflict with the Chalukyas of Badami in the north and the Tamil kingdoms of Chola and Pandyas in the south. The Pallavas were finally defeated by the Chola ruler Aditya I in the 9th century CE.

The Pallavas are most noted for their patronage of Hindu temple architecture, the finest example being the Shore Temple, a UNESCO World Heritage Site in Mamallapuram. Kancheepuram served as the capital of the Pallava kingdom. The dynasty left behind magnificent sculptures and temples and is recognized to have established the foundations of medieval South Indian architecture, which some scholars believe the ancient Hindu treatise Manasara inspired. They developed the Pallava script, from which Grantha ultimately took form. This script eventually led to several other Southeast Asian scripts such as Khmer.

The Chinese traveller Xuanzang visited Kanchipuram during Pallava's rule and narrated their benign rule. Pallavas were followers of Hinduism and made gifts of land to gods and Brahmins. People were living happily in this dynasty. Agricultural products were abundant. During this time, the village acted like a self-sufficient miniature republic. The major source of income was the revenue accrued from land. There were other forms of taxes on professions, marriages, manufacture of salt, sugar, and textiles, and draught cattle. Hiuen Tsang described that the people during this time were hard working and the soil was very fertile; the labourers who did agricultural work were paid in kind.

9.2.2 The Chalukyas dynasty (543-753 CE)

A few historians suggested that the Chalukyas originated from the profession of agriculturists. The Chalukya dynasty ruled a greater part of southern and central India during the 6th and 12th centuries.

Taxes in this dynasty were levied as the herjunka (tax on loads), the kirukula (tax on retail goods in transit), the bilkode (sales tax), the pannaya (betel tax), siddaya (land tax), and the vaddaravula (tax levied to support royalty). The Chalukya Dynasty was an ancient Indian empire that reigned over the Deccan Plateau [Deccan comes from the Sanskrit word Dakshina meaning "the south"]

in southern India (Pruthi, 2004). They controlled this region for over 600 years, between the sixth and twelfth centuries. Brahmanical Hinduism was the official religion throughout the Chalukya dynasty.

9.2.3 Kamarupa dynasties (350-1140 CE)

Kamarupa (Pragjyotisha -Kamarupa), was the first historical kingdom of Assam (along with Davaka). Land revenue (kara) was collected from cultivators, during this era, by special tax collectors. Cultivators who had no proprietary rights on the lands they tilled paid uparikara. Duties (sulka) were collected by toll collectors (Kaibarta) from merchants who plied keeled boats. The land was surveyed and classified. Arable lands (kshetra) were held individually or by families, whereas wastelands (khila) and forests were held collectively. No tax was levied on unsurveyed lands.

The land and revenue systems were introduced in Assam with the abolition of the old Paik and Khel systems. Thus, the British planted capitalism on the back of the feudal system. For winning the loyalty of the subjects, a part of the old middle class having western education was absorbed into the colonial administration. It is possible that in ancient times Pragjyotisa was an extensive Janapada from which Kamarupa came up in later times as a small kingdom.

9.2.4 Maratha dynasties (1674-1818 CE)

The Maratha Empire dominated a large portion of India during the 17th and 18th centuries. The Maratha Empire formally began with the rise of Chhatrapati Shivaji in 1674. The Maratha states came to form the largest block of princely states in the British Raj in terms of territory and population. The Raigad Fort served as the capital of the Maratha Empire in the 17th century. The Marathas weakened the Mughal control over the Indian subcontinent. Maratha's rule officially ended in 1818 with the defeat of Peshwa Bajirao II at the hands of the English East India Company. Religious tolerance and pluralism were important pillars of the state since they were fundamental beliefs of Shivaji. The Maratha Empire did not adhere to the caste system.

9.3 Hindu dynasties/kingdoms present during the transition between BCE & (CE)

9.3.1 Cheras dynasties (300 BCE-1102 CE)

In Chera society, the primary occupation of people was agriculture and pastoralism. The economy of Cheras was primarily based on pastoral-cum-agrarian active modern-day trade in the Indian Ocean. The emphasis on agriculture increased with time and provided the base for more significant economic change. The early historic south India (c. second-century BCE-c. third century CE) can be described as a semi-tribal political economy. The Chera dynasty was known for producing the finest quality steel in the world.

The Cheras were a Tamil royal dynasty of ancient Dravidian origin. They were the first to establish a historical ruling dynasty in the southern region of the country. Their society was largely agrarian and the majority of Cheras practised the Dravidian religions. They were ardent worshippers of Shiva, and women were accorded high status in society. Their architecture is known as Dravidian architecture. The reign of Cheras was dubbed the Glorious Period of South India because it saw a lot of progress and development in society, economy, and culture.

The Chera kingdom derived most of its wealth from maritime trade with the Middle East. The port of Kollam, which was under the control of the kingdom for most of its lifetime, was a major port in overseas trade to the Western and Eastern regions of Asia. Partially independent political units, controlled by powerful hereditary chiefs, occupied central importance in the structuring of the Chera kingdom.

9.3.2 Chola dynasties (300 BCE-1279 CE)

The Chola dynasty was a powerful medieval ruling dynasty that ruled large parts of southern India. The dynasty is known for daring naval and military expeditions against North India, Sri Lanka, Maldives, and Malaysia.

Agriculture and irrigation received good support from the Chola kings. A large number of wells were dug and tanks were constructed to assist farmers. The government under the Chola empire was divided into three main administrative units: central government, provincial government, and local government. Cholas made a significant development in their kingdom by using improved agricultural practices. Use of River Kaveri's silt as fertile soils in the riverbanks helped reaping good farm produce. The availability of more water also allowed farmers to grow more rice. Although agriculture had developed earlier in other parts of Tamil Nadu, it was only in the 5th or 6th century that this area was opened up for large-scale cultivation.

Forests had to be cleared in some regions, while the land had to be levelled in other areas. In the delta region, embankments had to be built to prevent flooding and canals were made for irrigating the farms. Double-cropping was made possible due to the use of irrigation artificially following different methods. In some areas, wells were dug, and tanks were constructed to collect rainwater to improve agriculture during the Chola rule. A good portion of income was spent on improving irrigation. The Chola kings were generous and gave importance to art and literature. Developments in agriculture were one of the many achievements of the Cholas. They made the best use of the river Cauvery, creating tributaries and building dams. They made the soil fertile and practised extensive agriculture. Karikala Chola built the first dam in India called the kallanai. The dam is still in use. Rice was grown primarily which became the source of food for the whole of south India.

The king would partake in the distribution of labour, planning of infrastructure, and collection of resources. For irrigation various methods were used. These included canal systems, stone dams, bunds, and wells which were dug to help farmers and other agriculturists; tanks were built for collection and storage of water. These people were the first to introduce rainwater harvesting to boost agriculture. Land survey and its assessment also began during this time and there was a reorganisation of the empire into units known as valanadus. One of the major sources of income of the king was land revenue. The Chola rulers actively encouraged the weaving industry and derived revenue from it. The most important weaving communities in early medieval times were the Saliyar and Kaikolar. During the Chola period, silk weaving attained a high degree, and Kanchipuram became one of the leading centres for silk.

9.3.3 Pandya dynasty (300 BCE -1343 CE)

The Pandya dynasty was one of the three major dynasties of south India; the two others were the Cholas and the Cheras (as discussed above). Many early Tamil inscriptions of Pandyas have been found in Madurai and its surroundings.

The political division of land was as follows: Salabogam (land assigned to Brahmins), Tattarkani (land designated to Ironsmiths), Taccu-maniyam (land assigned to Carpenters), and Bhattavriutti (land donated to the Brahmin group for imparting education).

9.3.4 Satavahana dynasties (100 BCE -225 CE)

The significant economic system of Satavahana and other contemporary dynasties was well-organized and systematic. There was all round development in the field of agriculture, industry, and trade during this period. Agriculture was

the main occupation of a large section of the people. The land ownership was both individual and state. The Satavahanas were based in the Deccan region. During the Satavahana period, several large settlements emerged in the fertile areas, especially along the major rivers. The amount of land under agricultural use also expanded significantly, as a result of forest clearance and the construction of irrigation reservoirs.

Kautilya suggested the division of land units into i) cultivated land, (ii) uncultivated land, iii) grove, iv) forest and v) pastures. Crops included rice, coarse grains, sesame, saffron, pulses, wheat, linseed, sugarcane, and mustard. Besides, a large number of vegetables and fruits were also grown.

10. Way forward

Many contemporary issues which are gaining importance across the world were, as a matter of fact, discussed, analyzed and adopted during the earlier Hindu scriptures, either directly or indirectly. Soil, per se may not be spelt in a very clear term of the word; however, earth, agriculture are always thought as a common issue to preserve the mother earth/ soil. The issues we are discussing today about soil quality, its preservation, ecosystem management, food production, addition of manures in soils to maintain its productivity and many other issues discussed below sounds similar and echo the earlier teachings of the Sages sitting in the primitive villages. This shows the vision of those knowledgeable and wise people about the Nature and its sustenance for mankind. A few examples are shown below which might be interesting for the readers.

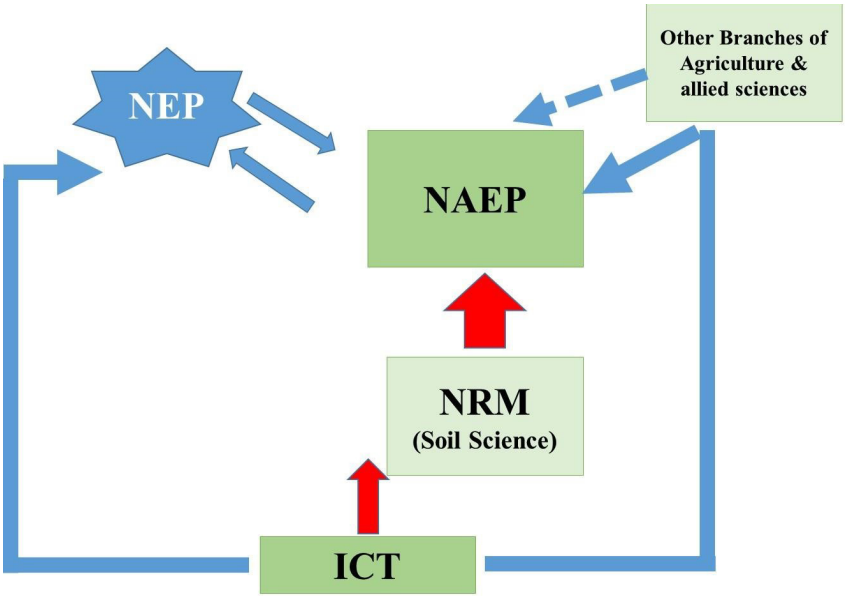
10.1 Soil studies and policy perspectives for the modern period: Background

Where soil is the backbone of agriculture (and its allied branches) as the source of food and other essentials as a part of natural resources, it is imperative to understand the soil and the natural resource research for its management. Given modern technologies available to almost everyone in the form of electronic devices, Information and Communication Technology (ICT) is making progress by leaps and bounds. This trend of modernism could be a boon for natural resource managers to spread the knowledge of the importance of soils as a medium of the ecosystem service provider to one and all.

The lack of human resource in disseminating agricultural technology can be overcome with the active participation of the student community armed with the latest ICT gadgets to reach the farmers and bridge the gap between state

agricultural universities (SAUs) and farming communities. This requires a shift and revision in the National Agricultural Education Policy (NAEP) concerning natural resource management (read soil science) (Figure 44). NAEP is required to address the issues for the future of NRM research so that the professors and the scientists can carry out future programmes and inform the students to ignite their inquisitive minds to understand contemporary issues. The entire exercise can be made easy if ICT is utilized in a meaningful way to be a part of the mainstream NAEP (Figure 44) and ultimately enrich the policy.

Figure 44: New Education Policy (NEP), New Agricultural Education Policy (NAEP), natural resource



management (NRM) and Information & Communication Technology (ICT): a suggestive Link.

As has been discussed, soil has always been the most important subject in the field of agriculture in ancient times throughout the world at different periods (Tables 11, 12) including information inventory, globally (Table 13) and in India (Table 14). The introduction of ICT tools has an immense influence today and continues to prevail during the modern period to shape the research agenda for future natural resource managers. New Education Policy (NEP) encompasses the NAEP where soil as one of the most important components of the natural resource shall have an important role.

Table 11: Chronology of ancient soil science (9000 BC/B.C.E. TO 1500 AD/C.E.) (Only a few selected events)

Period	Events elsewhere	Events in India
11000 BP	Jarmo village (Iraq) implements harvesting and tilling)	
9500 BC	Iraq (Irrigation evidence)	
5500 BC	Poland (beginning of cultivation)	
5000 -1700 BC	Mesopotamia	(understanding soil fertility)
3300 -332 BC	Egypt (Nile River civilization/ soil fertility and irrigation)	
2,500 BC -600 AD	----	knowledge acquired by the then agriculturists by experience has become tradition, and the same has been passed on from generation to generation
2300 BC	China (Soil grouping on quality and location)	----
2000- 1001 BC	Greece (Greek philosopher-scientists developed an understanding of soils and their differences)	----
1577 BC	----	The land is described as arid, wet (marshy), and moderate (neither too dry nor too wet) and is distinguished by six tastes through colour (Misra Chakrapani in Visva-Vallabha)

1000 BC	----	Oldest commandments of soils Atharva Veda. Five elements of life viz earth, water, energy, sky and air
500 BC	-----	Necessity of organic matter to nurture soils (The Ramayana)
401-500 BC	Mexico (farming included terracing and irrigation techniques)	---
321-296 BC	----	Kautilya Arthashashtra refers application of manures in soils
322 BC		Measurement and supervision of alluvial deposits for revenue purposes (Megasthenes during Maurya dynasty).
300 BC	-----	Fertile black (regur) soils in the Deccan Plateau
300 BC		Soil classification on the basis of suitability of crops
100 BC	China (fertile floodplain of the Huang He, or Yellow River)	---
300 AD	------	Fertile floodplains of the Ganga River, India included
1100 AD	China (Count Hui dividing soils according to their quality and location)	----

BC/BCE: Before Christ/Before the Common (or Current) Era; AD/C.E.: anno Domini/ Common Era; BP: Before Present; Sources: Brevik (2009); Katyal (2015); Velayutham et al. (2016)

Table 12: Chronology of ancient soil science (1500 AD/C.E. TO 2002 AD/C.E.)
(Only a few selected events)

Period	Events elsewhere	Events in India
1500 AD	Europe (soil formation/ biology)	--
1820 AD	Law of minimum J. von Liebig	--
1500-1800 AD	Chemical, geological, or biological components considered	--
1883 AD	Russian Chernozem publication by V.V. Dokuchaev1) recognized soil 1) as an independent natural body worthy of study in its own right, 2) established the five soil forming factors that are widely used and developed one of the first models of soil genesis, and 3) broadly introduced the concept of A, B, and C horizons	--
1880-1990 AD	National Soil Survey Programmes in many countries (Also see Table 13)	--
1880- 1990 AD	---	National Soil Survey Programmes in India (Also see Table 14)
1926 AD		Imperial Council of Agricultural Research (ICAR) registered as a Society
1938 AD	USDA Soil Taxonomy developed with three soil orders	

1946 AD		ICAR was renamed as the Indian Council of Agricultural Research
1969 AD		US soil taxonomy was adopted
1967, 1970 AD		Soil Test Crop Response (STCR) Project, Long-Term Fertilizer Experiments (LTFE) Project
1975 AD	US soil Taxonomy: seventh approximation	
2002 AD		Soil Map (Table 14)

Sources: Brevik (2009); Anonymous (2021); Soil Survey Staff (1975)

Table 13: National Soil Survey Programmes in countries

Country	Date
USA	1899
Russia	1908
Canada	1914
Australia	1920s
Great Britain	1920s
Mexico	1926
Sri Lanka	1930
China	1931
India	1932 (First Soil Map)
Poland	1935

Sources: Brevik (2009); Bhattacharyya (2021b)

Table 14: National Soil Survey Programmes in India

Year	Maps
1893	Voelcker (India)
1898	Leather (India
1932	Schokalskaya (Soil map of India)
1935	Wadia (Soil map of India: Geology))
1943	Vishwanath and Ukil (Soil map of India)

1963	Raychaudhuri (Soil map of India: 16 major and 108 minor soil regions)
1971	Govinda Rajan: World Soil Map Project
1983	Murthy, R.S. (Soil Map of India)
2002	Staff NBSSLUP (Soil Map of India) 1: 250000 scale

Source: Bhattacharyya (2021b)

The importance of soils is well recognized at the UN/FAO level since FAO has supported the formal establishment of World Soil Day (WSD) as a global awareness-raising platform. Like previous years, World Soil Day is themed as Soils: where food begins in 2022 (Table 2). This appraisal of soil science is vital since it transcends human life, expertise, and experiences by many generations, even centuries.

The immediate present and imminent future of any professional subject borrow its food for thought from its past. And that's why it is good to see through the prism of time the yesterday, today and tomorrow of soil science for natural resource management. An effort is made to mention a few important events related to agriculture, in general and soil, in particular. Many events are available in the literature. Major emphasis is shown here on the probable future events.

Semi-arid tropics extended from the sub-humid (moist) to arid climate in India showed a decreasing trend of soil organic carbon (SOC) stocks in India. Appropriate cropping systems along with proper management practices, have been suggested to restore and sequester organic carbon (OC) in soils of SAT (Chaudhury, 2016). Among cereals, paddy–paddy system with irrigation seems to be more beneficial for the higher amount of SOC sequestration. Continuous mono-cropping with cotton may be replaced by crop rotation with legumes to maintain soil fertility. For maintaining soil health in the future, various management practices are recommended by The International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Indian Council of Agricultural Research, National Bureau of Soil Survey & Land Use Planning (ICAR-NBSSLUP) and many other institutes (Bhattacharyya et al., 2006; Chaudhury, 2016; Sahrawat, 2005).

A package combined with proper cropping systems is for the improvement of soil health (Table 15). In sub-humid bioclimatic zones, soybean–wheat/fallow cropping systems with balanced fertilizers are recommended whereas in semi-arid or arid bio-climates, cotton with pigeon pea or chickpea with balanced nutrient and supplemental irrigation are also recommended in arid bioclimate to maintain threshold limit of SOC in soil.

Table 15: Suggested management practices in different cropping systems in three dominant bioclimatic systems in the semi-arid tropics

Bio-climate systems	Cropping systems	Range of MAR (mm)	Management practices followed	Comments*
Sub-humid	Soybean	1053–1209	• Soybean–wheat/fallow • Balanced fertilizer • FYM	In different bioclimatic areas within the given range of MAR for the particularly suitable cropping systems, if suggested management practices should follow properly, soil health in terms of SOC and SIC will be maintained.
Semi-arid	Cotton	660–975	• 2-year rotation of cotton + pigeon pea–sorghum–chickpea • Green manure	
	Paddy	632	• Irrigation • Balanced input	
Arid	Cotton	520–533	• Cotton + pigeon pea • Irrigation • Balanced fertilizer FYM • Green manure	

*Minimum threshold of SOC stock for identifying systems in SAT was estimated as 0.03 Pg/m ha (source: Bhattacharyya et al. 2006).

10.2 Soil studies for the modern period

Soil science, as an important component of the natural resource management discipline has made great strides in the past and is still doing well with the active support of talented scientists and professors in India and elsewhere. Soil science, however, needs to take a shift from the traditional research agendas to other areas of research encompassing a few subjects such as ecosystem services, soil diversity, pedodiversity, biodiversity, soil endemism, and geophagy (Bhattacharyya 2021 b, c; Brevik 2009) following the footprints of Vedic period learnings. Soil scientists must take a larger perspective instead of an isolated approach for the modern

period of concentrating primarily on agriculture and forestry; and to keep pace with the modern era of addressing all the growth engines of agriculture, including horticulture, fisheries, animal science, poultry, and other related fields.

Soil scientists need to forge links to harness interdisciplinary opportunities, as detailed later. There are many other contemporary issues like global warming, multifactor modelling of complex soil processes, remote sensing and IT applications for land use planning, and developing technologies for genetically modified crop-based systems that also require the broadening of the current paradigm of soil scientists (Minhas, 2006). Soil science and soil scientists need to be dynamic and should be ready to adopt midterm corrections for research agendas depending on societal and global necessities to keep pace with the modern period and its demand.

10.2.1 Soil information system

Soil science requires internationalization through its deeds and attitude. Therefore, all soil scientists must take a lead to decide the future of soils with its vast majority of technical resources and accordingly set their research agenda. Vedic literature suggests conservation of nature and to protect environment. This might be in tune with running the regional environmental modelling as a future research programme. This will require nationwide soil profiles and analytical databases, which should be established following the internationally accepted methodologies to put the database on the same global page. It should be carried out with Natural Resource Management (NRM) departments of state and central agencies, the Indian Council of Agricultural Research (ICAR), the United Nations (UN), Food and Agriculture Organization (FAO), and State Agricultural Universities (SAUs) as the focal points of research. This database should be accessible to all researchers globally following the standard protocol.

10.2.2 Fertilizer and /or nutrient management and land degradation neutrality (LDN)

A broader perspective of soil nutrient research may address burning issues like land degradation neutrality (LDN). LDN may also be conceptualized through fertilizer and /or nutrient management and ecosystem services. Since poor nutrient management leads to poor crop performance due to poor soil/land quality; it might as well invite land degradation and related ecosystem services. New range fertilizers and amalgamations as part of various treatments in long-term fertilizer experiments (LTFE) may be incorporated as a part of new treatments to test their effects on soil and crops (Figure 45). It might be a part of future recommended doses of fertilizers (RDF). ICAR and SAUs may lead and accordingly take appropriate initiatives in this regard.

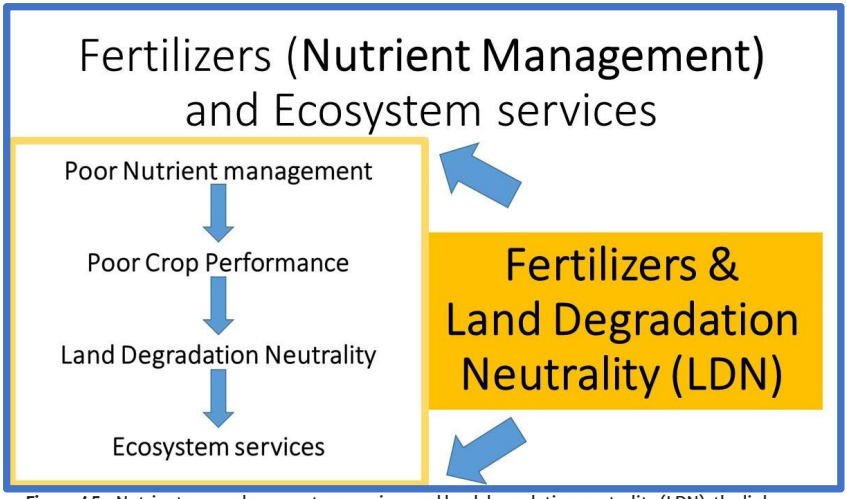


Figure 45: Nutrient research, ecosystem services and land degradation neutrality (LDN): the link.

The Long-Term Fertilizer Experiments (LTFEs) may be more contemporary and user-friendly. The findings of these studies need to reach the farmers through international research institutions, State Agricultural Universities (SAUs) to the respective state governments. The issue is that SAUs in India are the channels to reach the farming community, and LTFEs act as the eyes and ears of the central government. These experiments are excellent tools devised by our predecessors. However, since agriculture has different growth engines, LTFE may be oriented to address the issues of other sectors as well. There is scope to revisit, reshape, and reorganize the technical programmes to address the contemporary issues to solve the problems of the stakeholders at the field level. For the Long-Term Fertilizer Experiments (LTFEs), the various subjects may be considered in the future (Table 16).

Table 16: Revisiting Long-Term Fertilizer Experiments (LTFEs) of the Indian Council of Agricultural Research (ICAR)

Sl No.	Issues	Suggestions
1	LTFE database	• Database should be in a public-friendly domain following a standard protocol to ease data storage and sharing. • Digitisation of LTFE datasets with experts from IT Information Technology). • Information System on Long Term Fertilizer Experiment (ISLTFE)
2	FYM as a part of treatments and soil carbon	• To specify Organic Carbon(OC) content of Farm yard Manure (FYM) only • Very low active pool of organic carbon in black soils • Passive pool: recalcitrant and useless C reserve in soils. • Fresh and highly oxidised externally added FYM generates an active pool of Soil Organic Carbon (SOC) for plants • Splitting FYM into at least two doses (one for kharif and Rabi) shall improve soil and crop health. • For rabi crops (using residual soil moisture and/or with life-saving irrigation) a split dose of FYM shall improve the active pool of SOC.
3	Biofertilizers	Microbial population and its influence part of LTFE and laboratory studies for better soils and crop health.
4	Fertilizer applications	Ascertaining nutrient content at the time of application for each treatment.

5	Length of LTFE	Documentation on length of LTFE in terms of stabilization of soil health/ biotic stress/abiotic stress.
6	Methods of measuring parameters for soils	Standardization of method of measuring parameters
7	Including new fertilizer formulations	• Including new formulations with special reference to nano fertilizers and other amalgamations with carbon etc. in the treatments to bring in the mainstream of • Recommended Dose of Fertilisers (RDF).
8	Soil data	• LTFE datasets are skewed towards crops and fertilizers. • LTFEs should be rich in soil data. • Various parameters of soils should be regularly analysed in the future. • If SOC is measured by the Walkley-Black method Correct Walkley-Black Recovery Factor (WBRc) should be routinely measured
9	multi-disciplinary	LTFEs areconceptualized as a mul-ti-disciplinary programme. • Scope to make it broad-based
10	Predictive soil/crop models	• Predictive modelling using LTFE data is wanting in many cases for crops, weather, and soils. • It requires revisiting.

11	Doubling farmers' income (DFI) and soil health	• LTFE datasets may be oriented to address doubling farmers' income (DFI). • Agro-eco Sub Region (AESR)-based crop planning is in place. • LTFEs may be oriented to fit the concepts of bioclimatic systems (BCSs) in different • Agro-eco Regions/ Agro-eco Sub Regions/ Agro Climatic Zones • (AERs/AESRS/ACZs/BCSs) in India

LTFE: Long-Term Fertilizer Experiments; SAUs: State Agricultural Universities; FYM: farm Yard Manure; OC: Organic Carbon; SOC: soil Organic Carbon; BSR: Black Soil Region; RDF: Recommended Doses of Fertilizers; AESRs: Agro-Ecological Sub Regions; AERs: AgroEcological Regions; BCSs: Bioclimatic Systems; ACZs: Agro Climatic Zones. (Also see Bhattacharyya, 2022)

10.2.3 Land degradation neutrality and land use options

Land degradation is a process of ruining the planet, and destruction is caused by ignorance to of misusing the piece of land. Without healthy soils and productive land, there is hardly any possibility of sustainable development for decent life and living of man and survival of other biotic types. Humans are aware of this fact for ages. A verse in Prithvi Sukta (hymns to Mother Earth) (Atharva Veda, ~1000 BC) enunciated,

"Upon this handful of soil, our survival depends.
Husband it, and it will grow our food,
our fuel and our shelter and surround us with bounty.
Abuse it and the soil will collapse and die,
taking the man with it".

Ancient civilizations like the Roman Empire, Mesopotamians, Indus valley, and the Egyptians fell due to many reasons, among which soil degradation was one of the most important related to nature. Interestingly, ancient Vedic era always advised protecting nature against human interference. And to avoid soils being degraded they suggested using waste materials like leaves, cow dung, and other materials thrown into the agricultural land for decomposition.

To denote various types of degraded lands different names such as barren land, and pasture land was used. The Rig Veda also mentions making soils unproductive due to inappropriate use. There are mentions of degraded lands as wastelands in different Hindu dynasties also. In the Kamarupa dynasties, the land was surveyed and classified, which helped to decide the taxes on lands. Similarly, in the Mauryan regime, farmers were encouraged to cultivate fallow lands. Probably the purpose was to keep this natural resource under proper use to stop further degradation. In the modern era, this thought of keeping lands under appropriate use is also a concern for land resource managers which falls in line with the concept of ancient Hindu literatures.

Soil/land degradation is related to temporary/permanent soil loss. Temporary loss is associated with loss in soil quality, low crop yield and soil fertility. From ancient times humankind knew about the degradation of soils. There are mentions of resting soils to maintain their yielding ability. These days conservation tillage finds indirect mention in the Greek proverb like a field becomes exhausted by constant tillage. Soil fertility and its relation with human health advised people during ~1400 BCE to give back soil something it has been producing for so long (Brevik and Sauer, 2014). Holy Koran also suggested to recycle at least 1/3rd of what is taken out from soil: to stop its degradation (Deauraseh, 2010). There is a Kenyan proverb which sounds like soil is speaking to the human being: 'And soil said to man, take good care of me or else when I get hold of you, I will never let your soul go'. African saying sounds like a similar warning to stop abusing soil: ..." feed me to feed you". Koreans are more pious and faithful to soil/land as their proverb sermons: body and land are not two, but one.

Land degradation neutrality and land options could be dovetailed as a future exercise of land use planners to arrest further land degradation. People are thinking about the future of soil surveys in this country with particular reference to large-scale mapping. It might be oriented to address contemporary issues and may be demand-driven. Scientists and students will then be enthused to carry out the work both in the field and in laboratories (Figure 46).

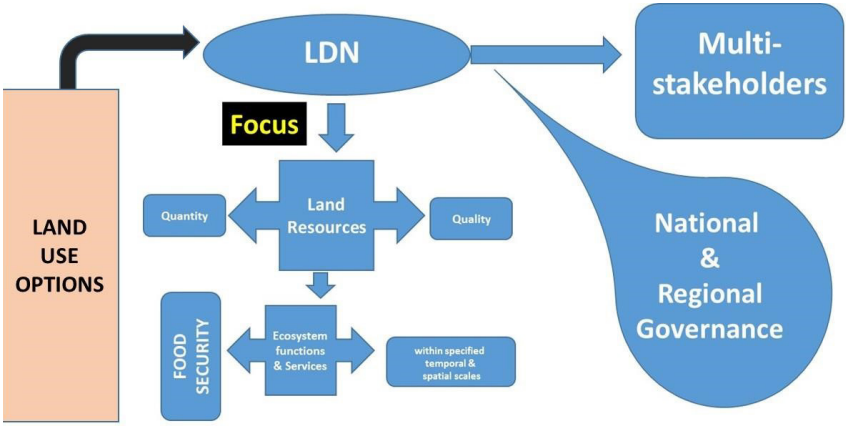


Figure 46: Land degradation neutrality and land use options: Role of stakeholders (Source: Bhattacharyya, 2020)

One of the major soil-forming factors is climate. Therefore, climate change and land degradation neutrality (LDN) vis-a-vis pedodiversity and biodiversity require soil as the focal point for discussion. Land area is dwindling due to many reasons of which the most important being its degradation, both natural and anthropogenic. But there are ways for research to find out how land degradation neutrality (LDN) may restore soil/pedodiversity and biodiversity. An example from the semi-arid bioclimate might help to visualize how the soils will look in the event of soil/land degradation going uncontrolled (Figure 50) (Bhattacharyya et al., 2016). Similar relations in other bioclimates may be constructed using new research ideas/data for all the 84 revised agro-eco subregions of the country (Figure 47) (Bhattacharyya et al., 2021a).

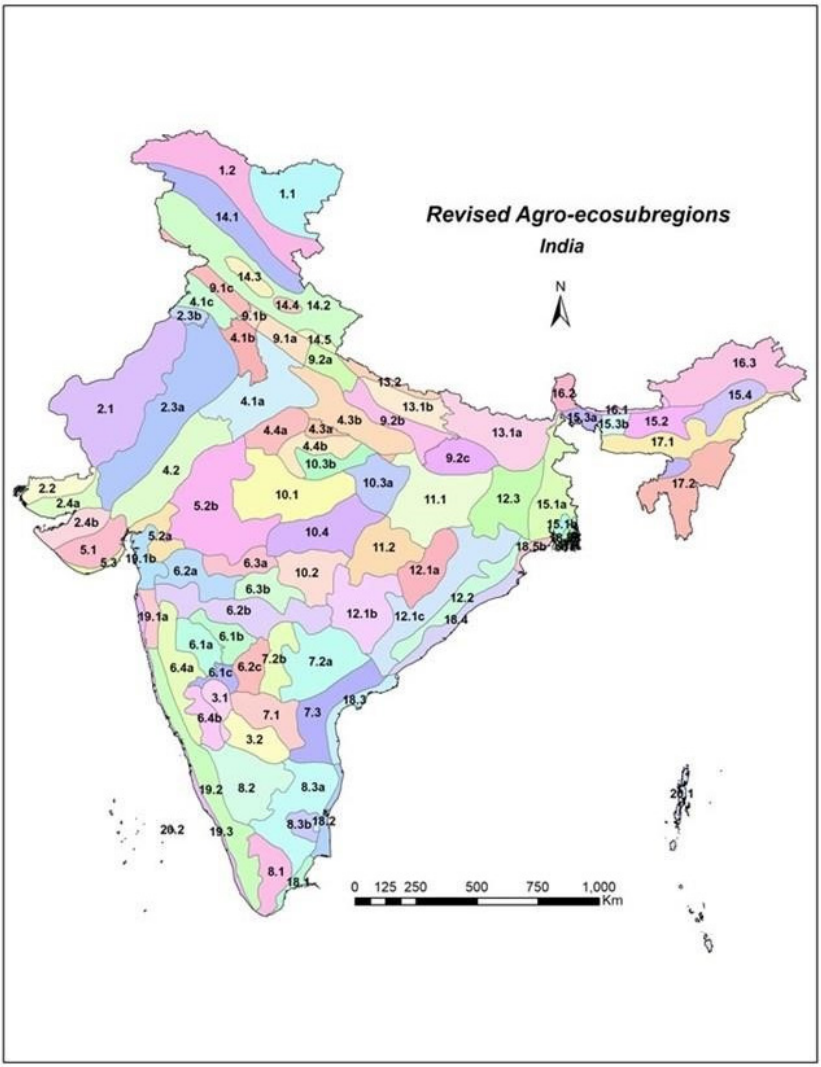


Figure 47: Agro eco sub-region (AESR) map of India revisited (Bhattacharyya et al, 2021a)

10.2.4 Soil ecosystems

Soil ecosystems remain firmly at the foundations of human life support systems. These are the least understood among the natural ecosystems and increasingly among the most degraded to demand attention. Soil and soil minerals are part of the natural environment. Soil studies should include many

other branches of science, in future research programmes, to understand soil ecosystems appropriately to make them interdisciplinary, multi-disciplinary, and transdisciplinary (Bhattacharyya, 2021c). Among these branches, soil and soil minerals are important components to provide almost all ecosystem services (Bhattacharyya 2021b) (Figure 48).

Four important ecosystem services soils provide are provisioning, regulating, cultural, and supporting services. The first one includes food, raw materials, and water retention, while the regulating services are climate, water regulation, carbon sequestration, and erosion and flood control. Weathering/ soil formation and nutrient recycling are the supporting services soils provide. Cultural heritage is the important cultural service soils provide for humanity. With the advancement in scientific knowledge and novel functionalities, new services might be discovered. Research on this aspect is to be a continued effort by students and researchers (Bhattacharyya 2022a).

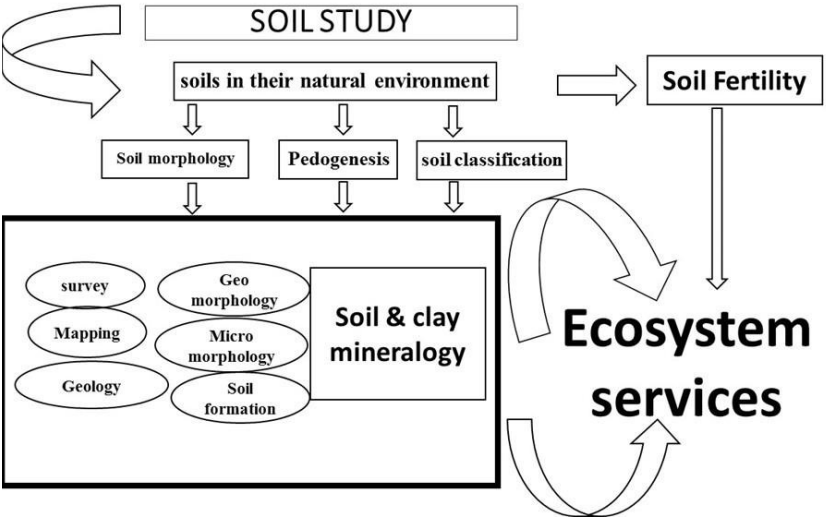


Figure 48: Relation between soils, minerals and ecosystem services (Bhattacharyya 2021c)

10.2.5 Soil carbon research

Soil and soil minerals are part of the natural environment. Both organic and inorganic soil carbon influence the vital component of ecosystem services soils provide. These include soil fertility and soil and clay minerals as part of the natural resource management vis-vis soil carbon (Figure 49) influencing different ecosystem services.

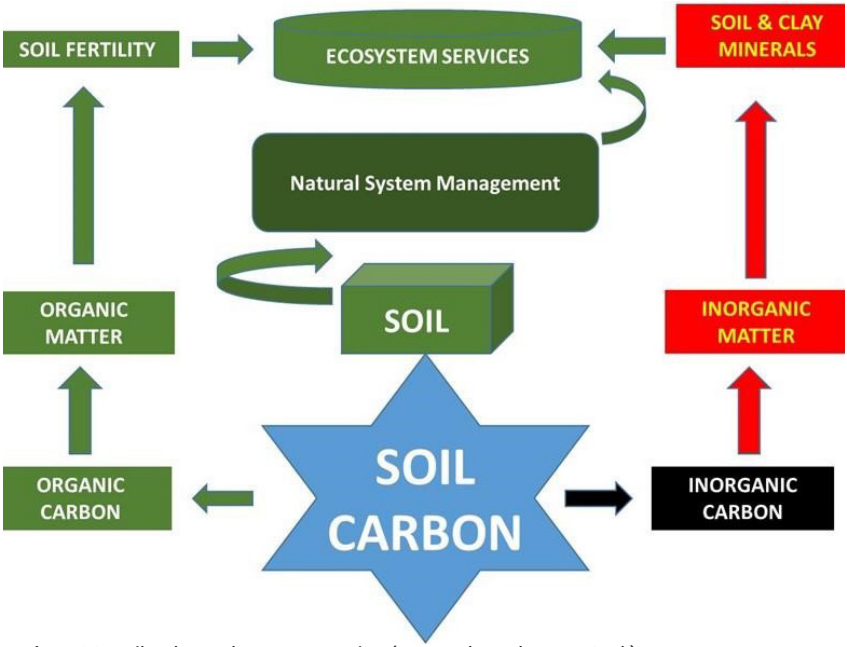


Figure 49: Soil Carbon and ecosystem services (Source: Bhattacharyya, 2022b)

Soil carbon regulates services in terms of sequestration of both organic and inorganic forms. Provisioning services centre on soil quality which requires a knowledge of soil carbon reserves and the prediction of carbon stocks over the years. This acts as a control and thus helps in understanding the deviation to predict the soil health, its quality and ability for crop yield. Both the forms of carbon in soils can help understand soil and land quality through a (proposed) soil and land quality (SOLAQ) model (Bhattacharyya, 2022). Therefore, information on soil carbon will ultimately help influence food, fuel, fibre, raw materials, and freshwater retention. The content of organic and inorganic carbon shall also influence supporting ecosystem services since both these two forms of soil carbon affect soil formation and nutrient recycling. The progress of a nation, as well as a declining civilisation, are the results of poor soil/land quality. Soil carbon dictates both. Thus, carbon in both its forms (organic and inorganic) shall continue to maintain cultural heritage to provide cultural services to humankind (Figure 50) (Bhattacharyya, 2021b, c, 2022). Research on both these forms of soil carbon and their influence on global warming may be a part of future soil carbon research.

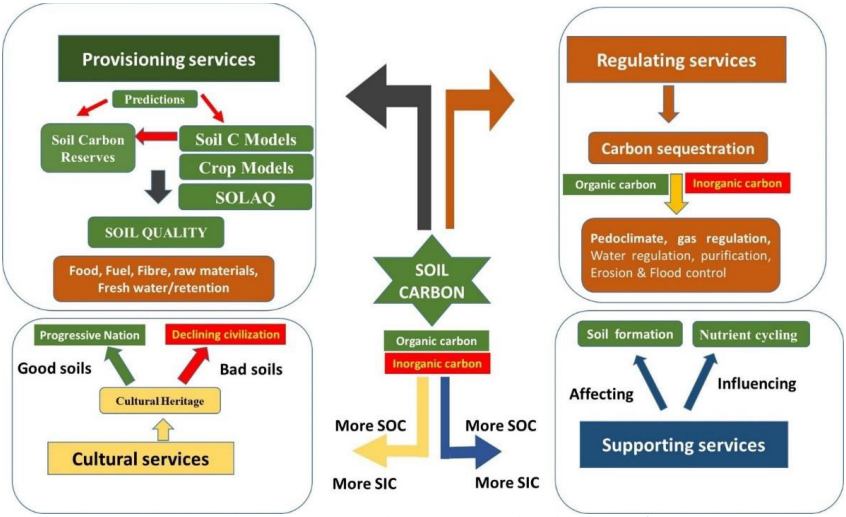


Figure 50: Soil organic and inorganic carbon, their Reserves and prediction to influence ecosystem services (SOC: soil organic carbon; SIC: soil inorganic carbon; SOLAQ: soil and land quality model)
(Source: Bhattacharyya, 2022b)

Different pools of organic carbon require an in-depth investigation in all the (revised) 84 AESRs (agroecological sub-regions) since these pools are influenced by climate. The addition of fresh farm yard manure (FYM) increases the active pool of soil organic carbon (very labile pool). Therefore, splitting FYM dose with one in the kharif season and the other in the rabi season with assured irrigation may be a subject of future research to benefit farmers growing rabi (winter) crops. Inorganic soil carbon requires a separate research agenda for the scientists engaged in abiotic stress management (Bhattacharyya, 2022).

10.2.6 Soil and human health

Soil microbiology and biochemistry should be strengthened in the future soil research programme to throw more light on biodiversity, soil-plant, and soil-chemical interactions in ecosystems to affect human life. Contamination of urban soils could be a part of Peri-urban agriculture research. Most of the world's population living in urban and suburban areas are exposed to soil-borne contaminants and pathogens through inhalation, ingestion, and dermal contact. More research may also be carried out by soil scientists to find the possible links between soils and animal/human health. Such information could be a part of a transdisciplinary research programme involving medical professionals.

10.2.7 Soil biology

Soil is a complex biomaterial on the planet. More than 90% of the planet's genetic biodiversity is resident in soils but less than 1% of the microorganisms have been cultured and studied. The enormous gene reserve in soils may be exploited in the future by industry and pharmaceutics with the help of soil microbiologists (Rao, 2006). Future projects may be oriented accordingly. With the advent of more sophisticated instruments, soil biologists may reveal the mystery of the structure–function relation of microbial communities. A greater understanding of the functional bridges with the available knowledge of basic sciences should find someplace on the agenda of future research in soil science (Rao, 2006). While generating a soil database, biological information was made an essential component of the soil information system (Bhattacharyya, 2014a, b). This research should be part of both course curricula and research programmes in the future soil science programme.

10.2.8 Pedodiversity and biodiversity

It has long been recognized that biodiversity can be the mechanism behind the performance of an ecosystem, particularly in communities of above-ground organisms. In soils below ground, however, the functioning of biodiversity is not well understood. The relationship between two interrelated aspects of natural diversity namely pedodiversity and biodiversity may be viewed in the image of a Mobius strip (Bhattacharyya and Patil, 2022). A Mobius strip is a curious and intriguing object that can be created with a strip having two surfaces, but once created, will give an illusion of having only one continuous surface.

Land use and its changes bring major changes in diversity. This could be changed in soil/pedodiversity leading to disturbed biodiversity. It requires the expertise of many researchers from different branches (Figure 51). The contribution of various experts is paramount not only from a biodiversity point of view but also in bringing some areas under agriculture and other allied activities. Future research in soils should focus to fulfil the target of land degradation neutrality (LDN) with an acceptable policy on climate change to converge the Mobius strip of biodiversity and pedodiversity (Figure 52).

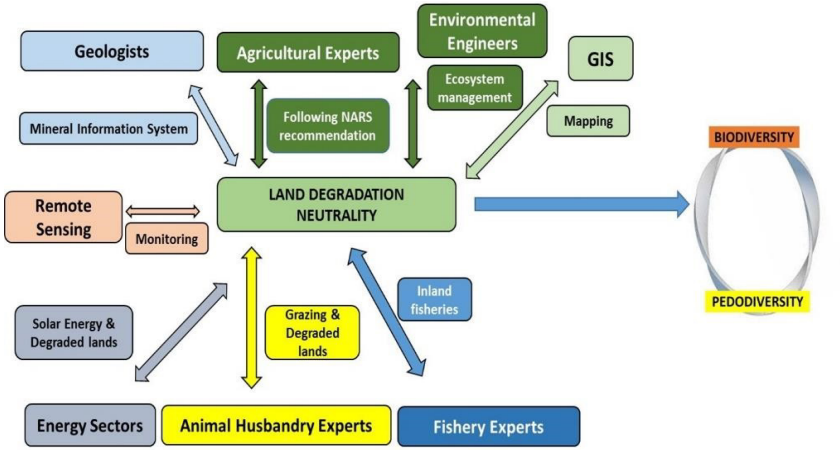


Figure 51: Land degradation neutrality (LDN) maintains soil/pedodiversity and biodiversity: suggested policy (Bhattacharyya and Patil, 2022)

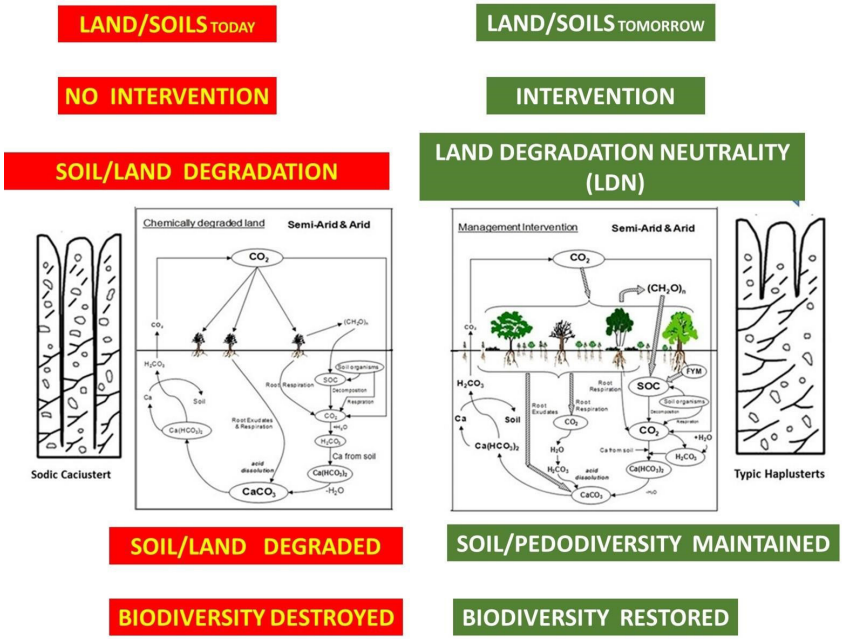


Figure 52: Addressing climate change and land degradation neutrality (LDN) vis-a-vis edodiversity and biodiversity (Bhattacharyya and Patil, 2022)

10.2.9 Quantifying relationships between pedodiversity and biodiversity with other forms of diversity in nature

Soil diversity research has been carried out in India scantily (Bhattacharyya, 2016, 2021 b, c). Soil and pedodiversity are linked so are their contribution to the key aspects of heritage such as biological and cultural (preservation of biodiversity, ancient and traditional sustainable practices), soil monitoring (benchmark soils in monitoring programs), prehistoric and paleontological (archive of artefacts and remnants of extinct species), bio-geosphere (archive of past environments), and geological (pedodiversity as a part of geodiversity concept). Relationships between pedodiversity and biodiversity with other forms of diversity in nature may be considered for future research programmes for soil studies (Figure 53).

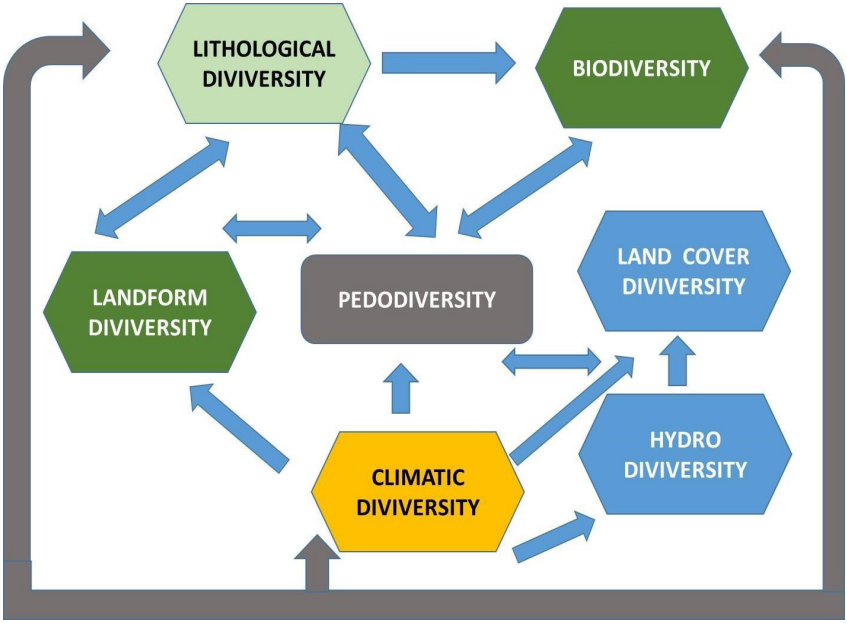


Figure 53: Relationships between pedodiversity, and biodiversity with other forms of diversity in nature (adapted from Ibáñez et al. 2012) (Bhattacharyya and Patil, 2022)

10.2.10 Soil endemism

There is a necessity to preserve the plant/tree species globally through the efforts of collecting them, planting them in orchards or botanical gardens, and carrying out an information campaign to keep them conserved in the wild. Efforts to preserve these unique characteristics of an important fruit like mango (Mangifera spp.) have been studied to ascertain the mango species under threat (Table 17).

Table 17: Mango species and tree endemism

Type of threat	Mango species
Rare	Mangifera andamanica, Mangifera camptosperma, and Mangifera gedebe
Endangered	Mangifera cochinchinensis, Mangifera flava, Mangifera lagenifera, Mangifera pentandra, Mangifera reba, and Mangifera superba
Vulnerable	Mangifera duperreana, Mangifera inocarpoides, Mangifera monandra, Mangifera timorensis, and Mangifera zeylanica

Source: Ganguli et al. (2019)

Like plant/tree species' threat to survive on earth, soil species (family or series in US soil taxonomy; Soil Survey Staff, 2006) indicate considerable soil endemism in the USA (and likely around the world). The trend towards endemism at the series and family levels of soil classification is of significant interest in conservation or preservation efforts. Soil endemism reflects, controls, and perhaps relates to the regional distribution of the plant species. And as described above, there is a jinx of the Mobius strip relation between soil diversity (read soil endemism) and biodiversity. These are complex relations in nature and need to be addressed regionally and globally for our survival. It is a key consideration in conservation and preservation planning and has yet to find any importance in Indian soil science research. A future soil research programme might include this aspect. This has more relevance while mapping degraded soils on a large scale to indicate the soils under threat for addressing land degradation neutrality (LDN) as detailed above.

10.2.11 Soil science as part of Natural Resource Management (NRM) and its non-agricultural application

The non-agricultural application of NRM may be a part of future research programmes involving soil scientists and other experts from other disciplines.

Space archaeology and tourism

Space archaeology, with the advent of GIS and other software techniques, can be made open to an online platform to launch citizen archaeology for easy access to historical sites and benchmark spots. This might help in informing the monitoring agencies about the existence of new sites not yet mapped and listed. While carrying out large-scale mapping programmes, soil scientists can be vigilant

about these sites during soil surveys and mapping. The experts in soil survey and mapping, remote sensing experts, and archaeologists can work together in this field of research.

This will stop the extent of damage caused by miscreants to stop vandalism and educate locals to understand the importance of these historical sites built many years ago and cannot be rebuilt (Bhattacharyya et al., 2022). This will lead to the conservation and maintenance of archaeological sites as a people's movement and would serve tremendously to boost tourism and may thus generate revenues for both the state and central governments (Figure 54). Such rural tourism can be a secondary source of income for the farmers and farming community.

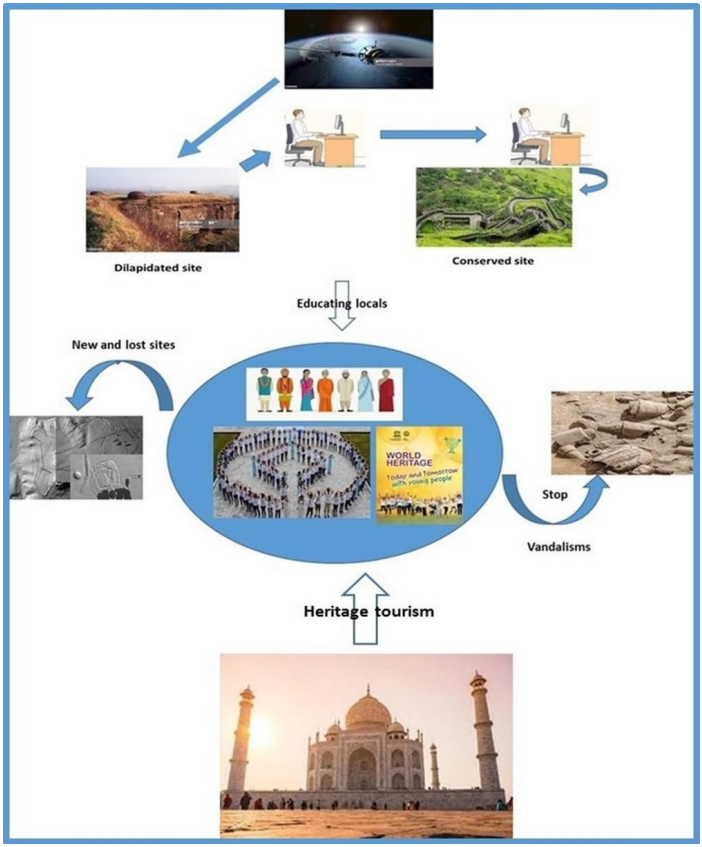


Figure 54: Space archaeology and soil survey can be complementary (Source: Bhattacharyya et al., 2022)

Natural resource managers, in addition, help to find out missing archaeological evidence (see above), may help in finding the source of various types of historical evidence through chemical, geochemical and mineralogical studies. Soil scientists may help other branches of science in this field of research in non-agricultural aspects. Such studies may form a future collaboration with soil scientists and archaeologists to find the historical truth.

There was discussion about the provenance of cannon balls in Goa, if it was from India or brought by the Portuguese from elsewhere. Archaeological, petrographic, mineralogical, and geochemical studies were carried out on samples of millstones and the quarried site at Dharavi (Uttan) as discussed earlier (Figure 18) (Ambekar et al., 2015).

10.3 Information & Communication Technology (ICT)/Digital India Programme

Information & Communication Technology (ICT) in the Digital India Programme is an interesting area and soil scientists have a great role to play in this field of research. There is a demand of natural resource databases by many organisations to supplement digital agriculture. It is in this context a national soil information system (SIS) and soil information technology (SIT) as a component of information technology (IT) might be useful (Bhattacharyya et al.,2014c; Bhattacharyya 2021 b, c). The electronic extension (e-Extension) mechanism may also be an essential component to help natural resource managers (Bhattacharyya et al., 2021b).

The introduction of farm facilitators (FFs) and lead farmers in the agricultural extension system (AES) provided the focal point of information dissemination at the village level. Creative and effective ways of disseminating the information developed during the Bhoochetana programme of the ICRISAT improved the adoption rate of agricultural technology among the farming community. Information related to soil fertility status was disseminated among the farmers through writing the information on the walls of schools or houses and through soil health cards.

Cellular telecommunication had a good network both in the urban and rural areas of India. Thus, cellular technology has become a very useful tool for dissemination mechanism through mobile marketing, where the service providers can directly communicate with the consumers and provide customized services.

Agricultural extension systems (AES) are already adapting mobile communication technology to change the livelihood of farmers through upscaling farming technologies (Patil et al., 2016; Bhattacharyya et al., 2021). Krishi Gyan Sagar (KGS), a tablet-based extension system, was developed by ICRISAT in collaboration with others (Wani et al., 2021).

The e-Extension has the potential to transform traditional farming into precision farming. Many countries rely on precision farming for increased productivity and profitability. Precision farming has economic, social, and environmental benefits. It requires the adoption of advanced technology. In most cases, technology is available, but its adoption rate is slow. The e Extension can play a crucial role to enhance the adoption rate of technology. The e-Devices and software may be used to ensure data logs from sensors and through feedback. Natural resource managers, including soil scientists may be involved to enhance access to technology, inputs, and advisory to improve the rate of adoption (Bhattacharyya et al., 2021b) by the farming community.

The involvement of both resource managers and the stakeholders (farming family) necessitates some degree of empowerment. Thus, the concept of empowerment may be a focal point of research so that the process of project management can be put into an appropriate, and contemporary context for soil scientists. This requires to be followed in Indian agriculture using ICT.

Relationship management influences empowerment and overall performance to accrue benefits (Figure 55) with particular reference to India and Indian farmers. An input-conversion output paradigm is used in terms of several incentives to the Indian farmers by the governments (Anonymous, 2020ad) which determine the effectiveness of the empowerment through various stimuli for the ultimate benefits of the society, in particular, and for the nation, at large. This scheme might be a model understanding to empower Indian farmers and may be sharpened with new concepts and case studies in days to come. Natural resource managers (soil scientists and others) should put such issues in their future research programmes.

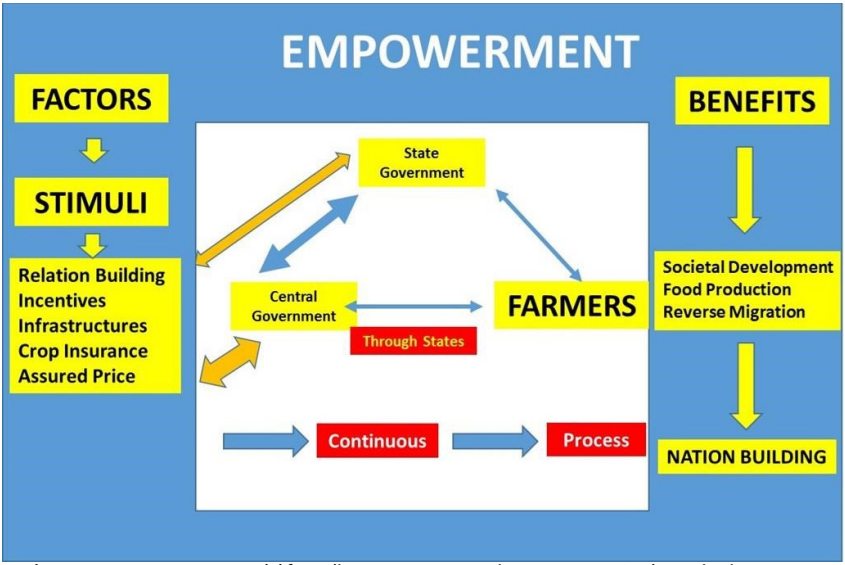


Figure 55: Empowerment Model for Indian Farmers as a continuous Process: A Schematic Diagram (Bhattacharyya et al. 2021b)

Initiatives of the Government of India and the Indian Council of Agricultural Research (ICAR) for empowering Indian farmers through the Digital India Programme are set to make India into a digitally empowered society and knowledge economy (Figure 56). This programme of digital media is one of the important tools to literate farmers and provide information to them about modern agricultural research and technology and to empower them in the future days (Soni Kumari, 2016; Bhattacharyya et al., 2021b).

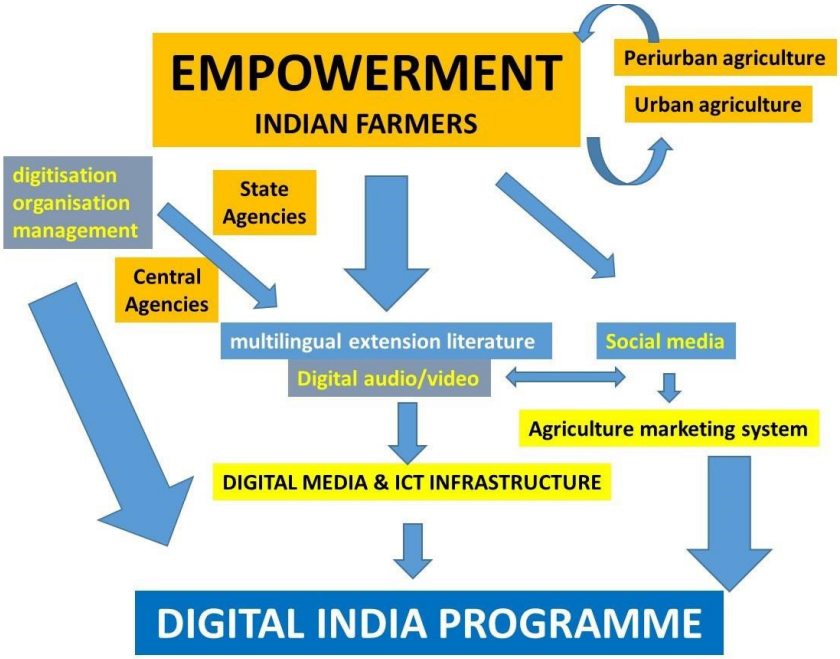


Figure 56: Empowerment of Indian Farmers through Digital India Programme.
(Bhattacharyya et al. 2021b)

Change of people's mindset through awareness and community participation is all the more important in the present-day scenario. From the Indian perspective, the example of Swachh Bharat involving the whole community to build public-private-people centric partnerships (PPPP) developed the rural and urban areas clean and environment-friendly. This indicates the success of the consortium approach between research institutions, NGOs and other line departments to increase synergy and creativity in tackling natural resource management (Wani, 2021).

Formation of consortium and empowerment of partners through capacity-building workshops for bringing all partners on the same page about goals, objectives and approaches as well as standard operating processes (SOPs) is critical (Bhattacharyya et al., 2021). To achieve the SDGs of zero hunger, no poverty and well-being through balanced nutrition of people in the country/region, scaling-up new technologies, knowledge, and products through building partnerships is essential (Wani et al., 2021).

Nearly 160 million ha area in India needs attention regarding better food production, resource management (Bhattacharyya et al., 2008), and scaling up research achievements to the farm level. Through upscaling techniques using line departments, government organizations, and NGOs, selected agro-eco sub-regions (AESRs) (Figure 51) can be brought back to sustainable agriculture. Soil scientists may earmark the AESRs using large-scale mapping techniques to save the soils under threat as discussed above.

Interestingly, many soils respond to management interventions due to their inherent resilience. The resilience of soils of SAT (semi-arid tropics) in India (Bhattacharyya et al., 2016) suggests that the chemically-degraded soils could be made vibrant crop production areas in future to feed the population. The degradation in dry arid regions with desert and coastal sand dunes and other areas needs to be scaled up and may form a part of future research programmes in soil science.

Other than major nutrient deficiencies, low levels of soil sulphur (S) and micronutrients in SAT are a great challenge for sustenance (Sahrawat et al., 2007, 2010, 2016; Sahrawat and Wani 2013). It appears necessary to include it in the regular soil test protocol. Moreover, this should be a part of the Soil Health Card Mission to help farmers to increase farm production. Initiatives are taken by ICRISAT, ICAR, SAUs and other government agencies to develop the necessary policy on this subject (Wani et al., 2021b).

Many soil scientists and natural resource managers are hesitant to talk about land degradation neutrality (LDN), even if their research is devoted to this area. This can be overcome if future research involves multi-disciplinary experts to fulfil the target of scaling up various technologies gathered by SAUs, ICAR, CGIAR (Consultative Group for International Agricultural Research), and many other organizations directly or indirectly working in these sectors with the active participation of the non-governmental organizations (NGOs) with an acceptable policy and target. The contribution of various experts is paramount in bringing some areas under agriculture and other allied activities. This will result in not only vertical but also the horizontal expansion of areas under agriculture, animal husbandry, fisheries, and other non-agricultural sectors. Bringing wasteland to harness a non-conventional source of energy can be doubly beneficial. Firstly, it will help use an alternate source of energy to reduce carbon footprints, and secondly, shall enable farmers to utilise the energy thus generated for operating various agricultural implements (Bhattacharyya 2020).

10.4 National Agricultural Education Policy (NAEP)

Future programmes related to NRM (soil science) require fresh talent in the SAUs and DUs (Deemed Universities) for training and education. This aspect demands a special mention in the New Agricultural Education Policy (NAEP). This policy must be linked with the future research agenda to benefit students and researchers.

10.4.1 The policy of education

National Agricultural Education Policy (NAEP) is a part of the National Education Policy (NEP) 2020. A few important issues related to NAEP include attracting talent in agriculture to make them suitable and efficient for the stakeholders and to make them more farming-friendly and to attract meritorious students to study in State Agricultural Universities (SAUs). Each student should be provided with incentives in one or another form depending on merit and other social reasons. Many Deemed Universities (DUs) (e.g., IARI, IVRI, and NDRI) provide fellowships for each of the M Sc and Ph D students admitted. Such facilities are not available in SAUs, for which many meritorious students opt for DUs for higher studies and if not selected, go for other alternative options. This is also true for students wanting to study soil science and subjects related to natural resource management (NRM). Even foreign students opt for the SAUs or DUs which are located in the metropolitan cities rather than in the remote rural areas of the country. This needs attention in NAEP.

Assurance of placement after completion of studies (common in many technological and management institutes) could be a way to incentivize students. This needs to be looked into while planning educational curricula in different SAUs. Placement of students as interns in the state-run/-controlled public sector agencies such as Agricultural Produce Marketing Corporation (APMCs), line departments, seed production agencies, and training centres run for farmers might help in employment generation as well as for the utilization of talent and youth.

Adding professionalism to agriculture and allied sciences such as soil science is necessary for the future growth of natural resource management both from a scientific point of view as well as for the overall benefit of society.

Agricultural graduates must come up with start-up ventures in a big way. This requires providing special packages for graduates volunteering to prastice agriculture with modern technology with special reference to ICT. Special concessions and subsidies to purchase farm machinery and equipment for the setting up custom-hiring centres are necessary to act as service providers, facilitators, or mediators between farmers and industry.

Keeping in mind the above issues, the National Agricultural Education Policy (NAEP) may be aligned with the National Education Policy (NEP) 2020 involving academic credit banks, integration of the campuses, and distributed learning systems, by creating students' mobility within the inter and intra university system. The challenge of the multi-disciplinary approach could be an issue to begin with. Remedial courses could be a probable solution.

ICAR is responsible for the quality of agricultural education across the country. It may be decided if ICAR will continue in its accreditation and grant-making roles with revisions. While developing the national agricultural education policy, students and their families may be consulted for their demands and aspirations. Besides, the professors taking classes, carrying out research in laboratories and fields, and being involved in extension work in the field may be a part of the decision-making process.

Except for a few deemed ICAR universities, ICAR scientists spend more time on research. For SAUs, the professors in different categories are engaged in teaching, research, and extension simultaneously and, in most cases, with a severe resource (fund and human resources) crunch. It may be noted that in the schematic diagram of NAEP (Figure 57). the dream of addressing future issues of agriculture, soil science, and natural resource management is also hidden. The entire group of professionals engaged in this field of research and education may try to liberate themselves from traditional thoughts and embrace the call for the development of Indian agriculture. A suggestive model of National Agricultural Education Policy (NAEP) and course curricula permitting the introduction of Vedic Learning Courses in NEP as well as NAEP right from school at the primary level might be a beginning of a New Era to embrace our forgotten ancient history (Figure 57).

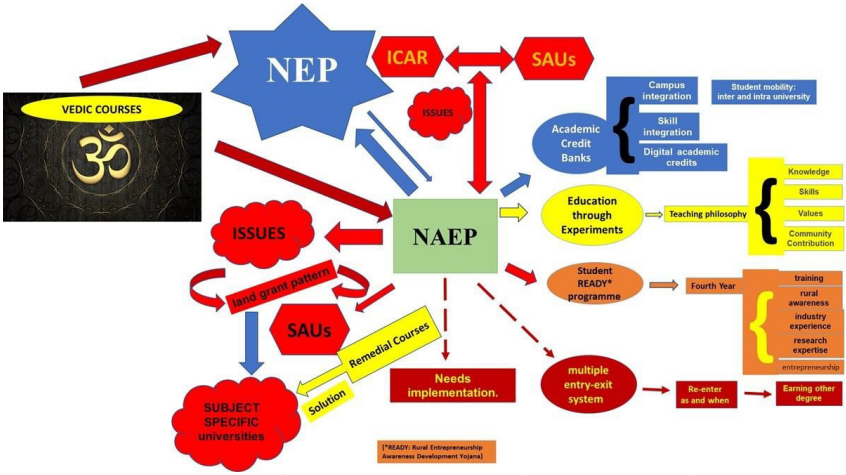


Figure 57: A suggestive Model of New agricultural education policy and course curricula permitting the introduction of Vedic Learning Courses in NEP as well as NAEP right from school at the primary level (Revised from Bhattacharyya 2022a)

To make the NAEP programme effective, we need highly motivated and patriotic teachers and researchers selected by equally dedicated selectors with strong motivation for nation-building (Bhattacharyya 2022). There is a scope for improved freedom for Vice-Chancellors and Chancellors of SAUs in terms of administrative, financial, and developmental decision-making to make educational and research organizations more up-to-date and meaningful. This might be possible with a clean, transparent, and fair selection of the lowest to the highest-ranking professionals. For the effective extension of agricultural research to the farming community, a completely different type of manpower may be developed by fine-tuning the existing process using the model selection procedure and a change in mindset. NAEP should be a dynamic process with scope for mid-term corrections.

10.4.2 The policy of research

Modern-day farming is heavily dependent on technologies that are born through research. These techniques are transferred to farmers through extension education and to Genext through agricultural education imparted in various SAUs and others. The state agricultural universities (SAUs) should ideally be the hub of all such activities and should continuously be fed through other institutions related to agriculture. Natural resource management, in particular, and agriculture, in general, are extremely important subjects and should be handled by professionals only. The suggestive plan (Figure 58) might help the planners and administrators in the way forward. It may be dove-tailed with the NAEP for future research

programmes to give the agricultural education and research policy of the country a suggestive new look. It might enable our SAUs to reach the international standards in the future (Figure 58).

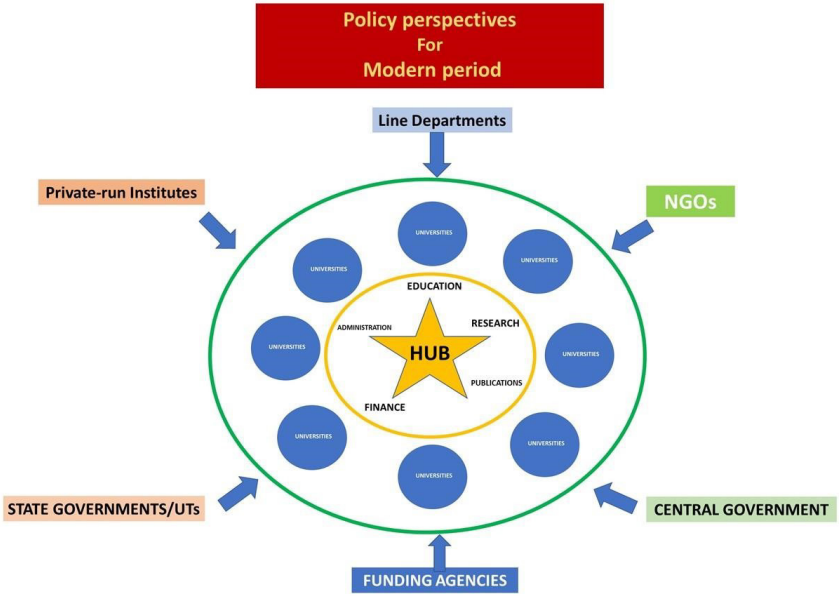


Figure 58: Suggestive Plan to strengthen research, education, and extension in State Agricultural Universities (SAUS) for empowering farmers in India: a futuristic model to bring Indian research systems at the international level (Revised from Bhattacharyya 2022a)

Research, education, and extension education require funds. Increased demand for social research and development shall need a regular supply of funds for development, infrastructure, and recurring expenditures. No organization can function at its full capacity to meet ever-increasing demand with low staff strength. It may be realized by the planners while preparing a policy for education and research.

Iceland spends 8% of gross domestic product (GDP) on education; the corresponding figures for Australia, Canada, Japan, the USA, and the UK are 5.6%, 5.4%, 3.7%, 5.4%, and 5.6, respectively (Anonymous, 2022a). A comparative analysis of expenditure on education by different nations shows that there is a scope for improvement on the part of India, spending nearly 3% (Figure 59). Nearly 0.7 % of the GDP was spent every year on development. This includes strengthening infrastructure of science and technology, during 2014-15 to 2018-19 (Anonymous, 2022ae) in India which may also be kept in mind while formulating new research agenda.

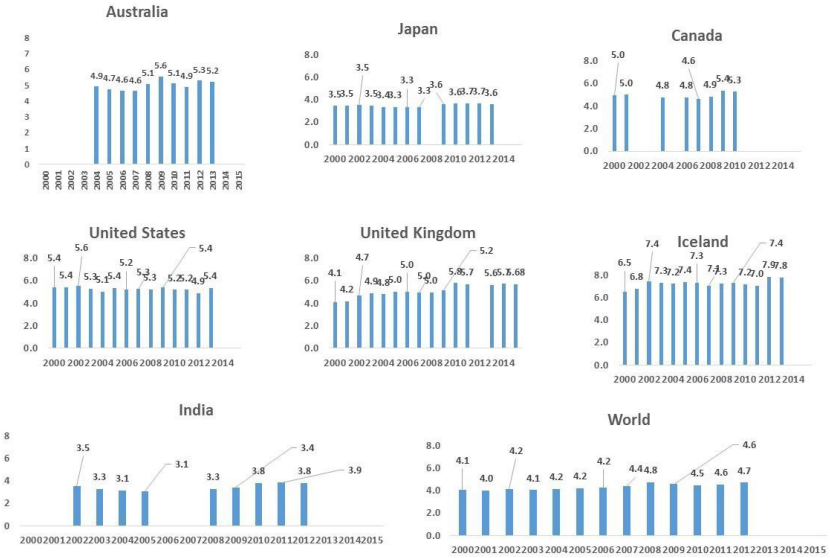


Figure 59: Expenditures on education by different countries: a comparison (values are % GDP) (Anonymous, 2022ad)

Studying the history of any field of research provides insights into how and to what degree the modern understandings and strengths of the modern era have imbibed and followed the cultural heritage of the past. It shows the strengths and weaknesses inherent in understanding the cultures of the past era. This requires retrospection, which can point out potentially promising new areas of study by identifying areas that have not received adequate attention. It can also identify past directions of study that were not fruitful and suggest the inclusion of the contemporary issues demanded by modern society.

The present effort of vesting the research and other studies related to soil science is only a very brief summary of major points in the history of natural resource management. There is much more to be explored.

Since the future lies in the hands of the students, it is mandatory on the part of researchers, professors, and research managers to understand the demand of students and society keeping because of our glorious past during the Vedic era. Changes may be imminent in this journey in the educational system, research agenda, and fare selection of merit. This will help in nation-building when our country is proudly be the torch-bearer for other nations.

11. Summary

In Prithvi Sukta, the Vedic seers solemnly declare the loyalty of humankind to mother Earth. Mata Bhumih Putroham Prithivyah meaning Earth is my mother, I am her son. (Kaur, 2013). Hindus believe that man was born from soil and will end with soil. In confirmation, it is written in Prasna Upanishad (Atharva Veda) that soil is one of the five elements (Panch Maha Bhuta) of life. These are kshiti (earth), jal (water), pawak (energy), gagan (sky), and sameera (air) and are all interconnected (Katyal, 2015).

Ancient Indian prayers command us to hold a deep reverence for life by reminding us of nature's great forces. In the prayer, the earth is personified as a lady with four hands and green colour. The morning prayer is called kardarshan as shown below.

समुद्रवसने देवि पर्वतस्तनमण्डले ।
विष्णुपत्नि नमस्तुभ्यं पादस्पर्शं क्षमस्वमे ॥

samudra vasane devi parvatastanamaṇḍale I
viṣṇupatni namastubhyaṁ pādasparśaṁ kṣamasvame ||

I salute you, O Bhumi Devi, who wears the clothes of the sea,
has the bosom of a mountain, and is the wife of Lord Vishnu.
Please Forgive my Touch of the Feet
(on Earth, which is Your Holy Body).

The villages and towns emerged as human settlements due to agriculture. Urbanization took place during the Bronze Age in the arid and semi-arid region of northwest India in the valleys of the Indus and the Saraswati rivers (now dry Ghaggar–Hakra bed), which is famous as the Indus or Harappan civilization (3500–1500 B.C.E.). The rest of India during this period consisted of the neolithic and chalcolithic farmers and Mesolithic people sustaining mostly on hunting.

The initiation of agriculture (~ 8000 years ago) made a sea change in the economy, technology, and demography of human societies. Hunters, till such time, residing in the hilly forested areas, shifted to the plains with fertile soil and perennial water availability. Vedic agricultural system was enriched. Vedic farmers knew the use of an external source of water for irrigation in the absence of rainfall. They were

also aware of controlling natural calamities and preserving agricultural produce for bad days. The advancement of any field work depends on long experience. Hence, the Vedic agricultural system is the pioneer of the modern agricultural system in India to provide adequate food to every person in this country. This is why people should think about going back to basics to learn more about agriculture and soil management for saving nature (Figure 60).

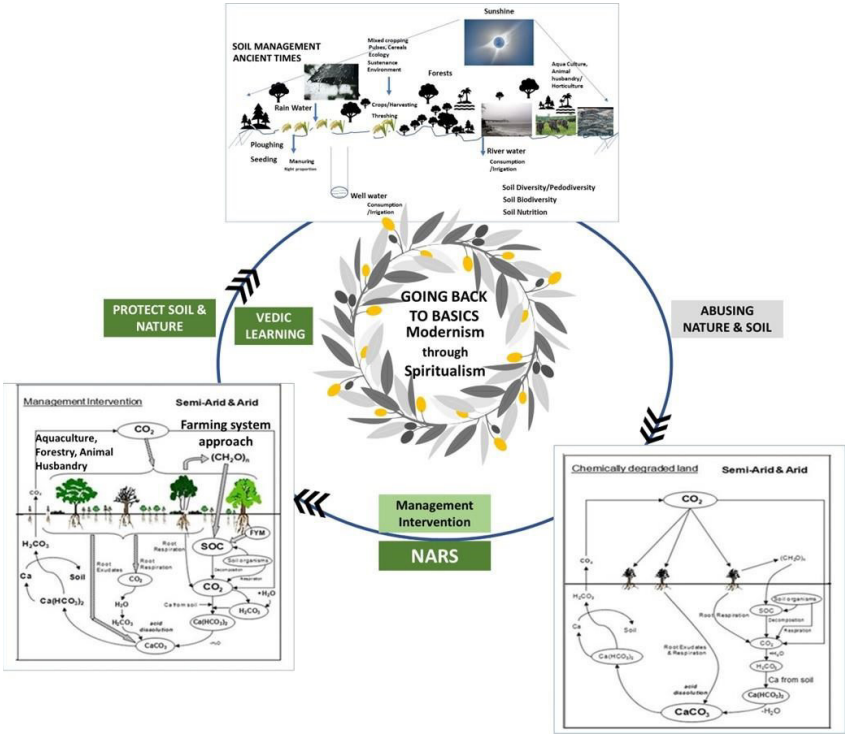


Figure 60: Figure 60. Going back to Vedic Learnings to combat soil abuse to maintain soil fertility to save nature following the path of spiritualism (NARS: National Agriculture Research Service; Also see, Bhattacharyya et al, 2004)

The Upanishad suggests not to differentiate between the world (we perceive) and the Divine (the source of all living beings). Vedas, the world's most ancient sacred texts, indicate the love of ecology and the love of Mother Earth/soil, which form the two burning issues to protect our nature from climate change and global warming. Farmers engaged in agriculture and allied works, were aware of the nature of soils and their influence on crop yield in ancient India. Vast knowledge gathered over years (2500 BCE to 600 CE) by the farmers was carried over from generations after generations mostly through pastoral songs, maxims, and various

proverbs. One such knowledge was to group soils according to their fertility to help the owners to pay taxes. And that is why the soils were urvara (Sanskrit meaning fertile) and anurvara or usara (Sanskrit meaning unfertile or sterile), as mentioned before.

Ancient India witnessed many developments in science, mathematics, civilization, and agriculture. They were aware of the fact that soil is the ultimate result of the interaction of various factors such as climate (atmosphere, hydrosphere), relief (biosphere), organisms (biosphere), parent material (pedosphere), and time. The link between soils and human health was well-known. The uptake of heavy metals by plants and subsequent accumulation along the food chain is a potential threat to human health was also known.

Ancient people in India were also aware of the application of fertilizers (in mineral form), other than manure. It was known that the addition of fertile soils to relatively infertile soils shall lead to higher soil fertility. Traditional agriculture has adaptive and mitigation abilities towards various anthropogenic threats. These practices help maintain the natural balance of ecology and soil health. The conventional farming system is based on the ecological principle, and the interaction between the human environment and existing natural resources also addressed many issues which in modern days form a few of the UN Sustainable Development Goals (SDGs). The present-day digital media and/e-extension, amalgamated with Vedic agriculture, may solve most of the natural and anthropogenic problems of modern civilization (Please see Figure 60).

Vedic agricultural practices transcended various Hindu dynasties. Before the Christian Era (BCE), the Maurya dynasties took great care to promote agriculture. Categorizations of soils, the use of meteorological observations, and the construction of a dam for using water for agriculture were features of the Mauryan Empire (322–184 BCE). Besides, the Pallavas, a major Dravidian power, and the followers of Hinduism made gifts of land to gods and Brahmins during the Christian Era (CE). Pallavas thought about making the village act like a self-sufficient miniature republic in the Pallava period. Land revenue was the major source of income. The Pallavas also levied taxes on professions, marriages, the manufacture of salt, sugar, and textiles, and draught cattle. It is evident from the testimony of Hiuen Tsang that the people were very hard working and the soil was very fertile and the labourers who did agricultural work were paid in kind.

The Chola dynasties supported agriculture and irrigation in a big way. A large number of wells were dug and tanks were constructed to assist farmers. Water from the channels provided the necessary moisture for agriculture, so

beneficial for growing rice. Although agriculture had developed earlier in other parts of Tamil Nadu, India, it was only in the 5th or the 6th century that this area witnessed large-scale cultivation due to the availability of irrigation, so necessary for agriculture.

The introduction of ICT tools in agriculture and natural resource management has an immense influence today. It should continue to shape the research agenda for future natural resource managers. New Education Policy (NEP) encompasses the National Agricultural Education Policy (NAEP), where soil, as one of the most important components of the natural resource, shall have an important role if dovetailed with the teachings of the Vedic Era (Figures 58, 60). There is a scope to include Vedic literature in connection with agriculture and other branches of education for developing an overall discipline in our behaviour towards nature and society and collecting invaluable gems of learnings from our predecessors (Also see Figures 57,58,60).

Studying the history of any field of research provides insight into how modern understandings and strengths have arrived in that field. The present effort of merging the research and other studies related to soils and agriculture with Hinduism and its scriptures is only a summary of significant points in the history of natural resource management. The scientists and/or professors are in a mode of searching, searching for truth, understanding, and comprehending nature to manage these vast natural resources. Since the future lies in the hands of the students, it is mandatory on the part of researchers, professors, and research managers to understand the demand of students and society. Changes may be imminent in this journey in the educational system, research agenda, and other issues (Bhattacharyya 2022). This will help in nation-building when our country is proudly the pioneer in bridging the human mind and science to excel in this modern era. The Vedic learnings could be used as a wealth of information.

In this connection, this divine verse might help us remember our attitudes and our duties to soils/lands. These pronouncements binding societal actions to maintain soil health scripted some 3000 years ago seem relevant even today.

So long as the land will have mountains, forests, and pastures,
that long will the earth survive.
Sustaining you and the next generations

Hinduism is not a religion but a way of life. Unlike other religions, Hindu dharma has many specialties. It refers to Sanatan Dharma where Sanatan means which cannot be destroyed by fire, weapons, water, and air, and which is present in all living and non-living beings (Ref. the Bhagvad Gita); Dharma means, the way of life which is the total of all aachaaraas (customs and rituals) (Anonymous, 2022af). The Vedas, the Upanishads, the Gita, the Ramayan, the Mahabharat, the Puranas, the books on the six systems of philosophy, the songs of the Bhakti movements, and the mystics are all authoritative. Still, none is exclusively so (Sen, 1961). There are different schools of thought. All these make Hinduism an ocean of knowledge. During the last two hundred and fifty years, Hinduism has been influenced by many. This includes Raja Rammohan Roy (1774-1833), a scholar and founder of the Brahmo Samaj), Maharshi Devendranath Tagore (1817-1905) (a saintly character and the follower of Raja Rammohan Roy), Swami Dayanand Saraswati (1824-1823) (Arya Samaj fame), Ramakrishna Paramahamsha (1834-1886, Bhakti movement, belief in a Lovable Almighty God), and his disciple Swami Vivekananda (1862-1902, Vedantic doctrine of Advaita meaning nondualism) and Raman Maharshi [1879-1950, the doctrine of the Atman (soul) to ask who are you?]. Besides, other names which need a mention are Shri Aurobindo Ghose (1872-1950, Yoga: a school of Hinduism) and Mahatma Gandhi (1869-1948, making the teachings of the Gita into a living faith) (Sen, 1961). Hinduism believes in reaching the Supreme in many ways. Hindus have a strong faith in craving for the Supreme that also reverberates through the Upanishads as mentioned below:

य एकोऽवर्णो बहुधा शक्तियोगाद्
वरणाननेकान निहितार्थो दधाति ।
विचैति चान्ते विश्वमादौ च देवः
स नो बुद्ध्या शुभया संयुक्तु ॥ १ ॥

ya ekovarṇo bahudhā śaktiyogād
varaṇān anekān nihitārtho dadhāti |
vicaiti cānte viśvam ādau ca devaḥ
sa no buddhyā śubhayā saṁyaktu || 1 ||

He who is one, and who dispenses the inherent needs
of all peoples and all times,
who is at the beginning and the end of all things,
may He unite us with the bond of Goodwill

It sounds like the role of Mother Earth and Soil, which fulfils everyone's needs. May the Soil bind us all forever and for generations. Let us modernize the concept of managing soils/agriculture by following the path of spiritualism.

Om Shanti!

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Title of the Book: Soils in Hindu Scriptures including Jainism, Buddhism, and Sikhism)

Relationships of human/nature (yagna), human/divine (tapas), and human/human (dana) are conceptualized to stitch man and nature through soil, soul, and society as described by the Gita. This suggests a high level of realization to connect these three to have a harmonious relationship with nature and sustain human civilization. All religions address soils differently and portray diverse cultural patterns of understanding this valuable natural resource. According to Hindu religious belief, soil (matter, nature) is considered divine and respected as Mother. Soil is seen as a feminine donor, attributed predominantly to chthonic properties in Hinduism (Dhartī: Mother Earth) and also related to cosmic elements. In Buddhism, the soil is described as a symbol of dust in this ephemeral world to support life. Humans belong to nature, and when they cultivate soil, it always reverberates in their minds. To relate humans with soils, two types of religious concepts, natural and salvation, are postulated. During the long history of human civilization, with primal religion being dominant, the soil has been considered supernatural and controlled by an unseen power. Soils are part of religious reverence, justifying certain rituals to sustain their fertility. However, the modern-day approach to soils considers the environment, ethics, and ecology more important. Human ecology is related to human concepts of nature and destiny (religion). Hindu religion always considers land/soil as mother earth, cautions about its use and abuse, and recommends its preservation for posterity. Given this, Hinduism and other regions such as Jainism, Buddhism, and Sikhism, as well as their concept, indirectly believe in the environment and ecological sustenance. They are in line with the modern-day concept.

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