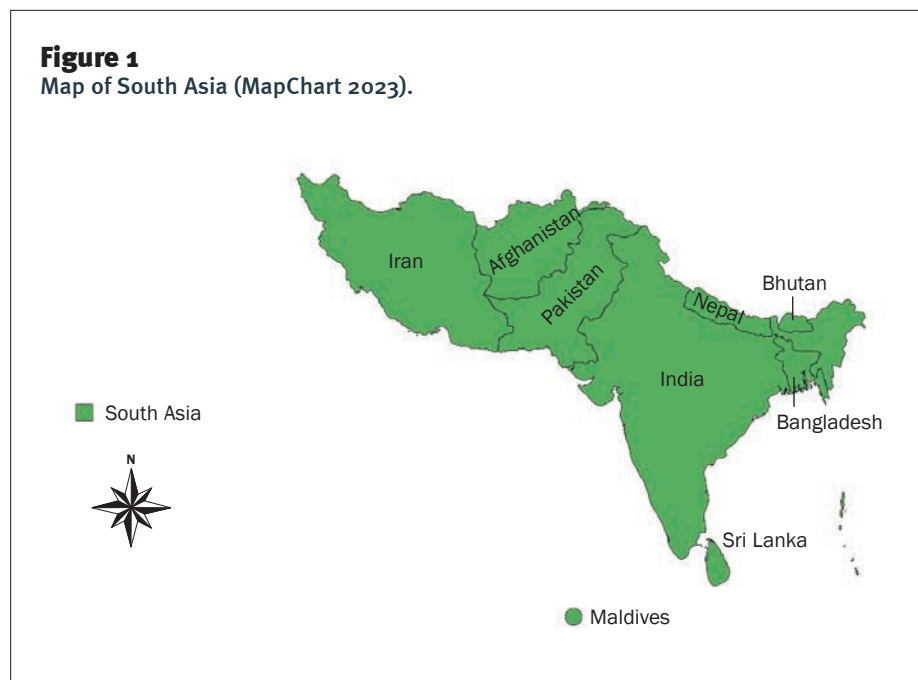


Restoring South Asia's degraded soils and ecosystems for peace and prosperity

Rattan Lal

South Asia (SA), a subcontinent, is the world's most densely populated region. It consists of nine countries: Afghanistan, Bangladesh, Bhutan, India, Iran, Maldives, Nepal, Pakistan, and Sri Lanka (figure 1). Myanmar and Tibet are also sometimes included in the SA region but won't be included in this article. SA is a region with common geography, history, culture, language, and religions. The SA region has the world's highest mountain ecosystem, the Himalayas, also called the Third Pole (Chaudhary et al. 2023). It also faces serious challenges of ecological degradation, which transcend beyond political boundaries and jeopardize global peace and political stability. Important among these issues are climate change, food and nutrition insecurity, soil degradation/pollution along with extinct/endangered and peak soils, water scarcity, and eutrophication, which exacerbate the flood-drought syndrome. The latter is aggravated by denudation of the landscape, excessive grazing, and deforestation of ecologically sensitive ecoregions. Additionally, pollution of air quality is aggravated by in-field burning of crop residues and attendant emission of soot and greenhouse gases, which create positive feedbacks to global warming. Ecological degradation in SA, a complex issue, is driven by a wide range of interacting factors, including rapid population growth, urbanization, industrialization, rapid deforestation, economic growth, poverty, and a high dependence on natural resources (Sultana et al. 2022; EFSAS 2021; Chaudhary et al. 2023; Ajmal 2023). These degradation processes perpetuate the threats of undernutrition and malnutrition as well as decline in human health and well-being to a large proportion of the population. They also increase risks of political instability, civil strife, soil/climate refugees, and war among nations of the SA region (figure 2). Indeed, soil and ecological degradation is the common enemy of



all countries in SA, and they must cooperate, work together, and effectively address this menace.

Thus, the objective of this article is to describe the common and hideous enemy of SA: soil and ecological degradation with its cascading adverse effects leading to human suffering; poverty; environmental pollution; global warming; political instability at local, regional, and global levels; and hostilities among neighboring countries. The specific hypothesis of the article is that restoring degraded soils and the polluted environment is critical to achieving human well-being and accomplishing lasting peace and harmony in SA.

GEOGRAPHY, CLIMATE, BIOMES, AND AGRICULTURE

South Asia, also referred to as the Indian subcontinent (McLeod 2002), has a distinct geographical identity (figure 1). Tectonically, it is influenced by the Indian Plate, which rises above sea level as the Indian subcontinent. Geographically, SA

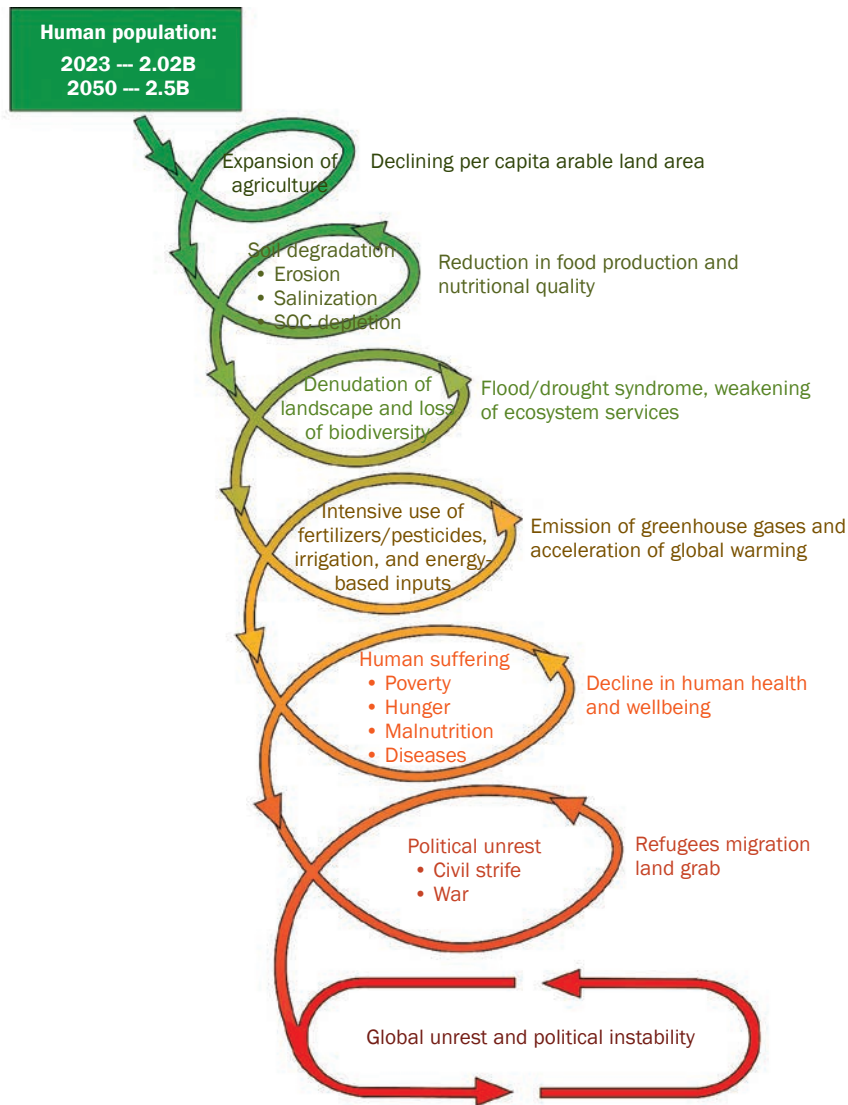
is bordered by the Himalayas and central Asia in north, west Asia in west, northeastern Asia in east, and the Indian Ocean in south (figure 1). SA, with a land area of 6.75×10^6 km² (2.61×10^6 mi²), is home to 25% of the world population. Thus, SA is the most densely populated region of the world. The population of 2.02 billion in 2023 is projected to reach ~2.5 billion by 2050 with an average annual growth rate of 1.0295% (World Bank 2023).

Because of the wide range of climate, physiography, and vegetation, SA has numerous ecoregions or biomes. Different ecoregions, geographically defined areas, contain distinct assemblages and communities identified within each biome. Davidar (2017) identified and described eight terrestrial biomes or ecoregions in SA as follows: (1) tropical and subtropical wet broadleaf forests, (2) tropical moist

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Figure 2
Prevalence of soil and ecological degradation leading to political instability and regional conflicts.



deciduous forests, (3) tropical dry broadleaf forests, (4) temperate and mixed broadleaf and coniferous forests, (5) tropical, subtropical, and temperate coniferous forests, (6) grasslands and savannas, (7) deserts, and (8) mangroves.

The rapidly growing and increasingly affluent population has strong impacts on these biomes. Most threatened are grasslands and mountain forest biomes of the Himalayas and mangroves of Sundarbans. Forests of SA are being destroyed by rapid deforestation and urbanization. The desert is spreading at the rate of 100 ha yr^{-1} (247 ac

yr^{-1}), which may change 13,000 ha (32,124 ac) of cropland into desert in India and Pakistan by 2100 (Hasnat et al. 2018).

Hunger statistics for SA, on an increasing trend since 2016, are a major concern because of global ramifications. The trend of prevalence of undernutrition (PoU) in SA was 11.9% in 2016, 13.3% in 2017, 15.5% in 2018, 16.3% in 2019, 18.9% in 2020, and 21.0% in 2021 (Ganbold 2023). In comparison, PoU in Africa is 20.2% (FAO et al. 2022). Despite being the target of Sustainable Development Goals (SDGs) by 2030 (UN 2015), the hunger gap (SDG

#2) is widening because of the growing prevalence of poverty and lack of access to adequate and nutritious food to masses in SA and Africa, which is a serious global challenge. The PoU and malnutrition is a dilemma in SA (and Africa) because cropland and agricultural lands cover 43.1% ($2.437 \times 10^8 \text{ ha}$ [$6.022 \times 10^8 \text{ ac}$]) and 56.9% ($2.841 \times 10^8 \text{ ha}$ [$7.02 \times 10^8 \text{ ac}$]) of the total land area (tables 1 and 2), respectively, and agricultural productivity has increased drastically since the Green Revolution of 1960s.

Per capita cropland and agricultural land area in SA countries are on the decline due to rapid population increase. Between 2011 and 2050, per capita cropland area may decline from 0.139 ha to 0.099 ha (0.343 to 0.245 ac; table 3). By 2050, SA will have per capita agricultural land area of 0.155 ha (0.383 ac) and forest land area of 0.044 ha (0.109 ac; table 3). The optimum per capita arable land area, to provide all essential ecosystem services, is estimated at $\sim 0.25 \text{ ha}$ (0.62 ac).

An estimated 60% of rural households in SA practice agriculture as the primary mean of their livelihood. Most farmers in SA, as those in sub-Saharan Africa, are small landholders. An estimated 100 million small landholder farmers practice agriculture in SA. It is estimated that 80% of food consumed by people in SA is produced by landholders who cultivate less than 5 ha (12 ac). Agricultural productivity, and nutritional quality of the food produced, is adversely affected by soil degradation, global warming, and lack of availability of essential inputs (e.g., irrigation, machinery, fertilizers, need of improved varieties). Agronomic productivity is moderated by soil organic carbon (SOC) content, plant available water and nutrient capacity of the root zone, and structure of soil as determined by aggregation and their stability in relation to compaction, water infiltrability, erodibility, and susceptibility to secondary salinization. Problems of soil degradation in smallholder farmers of SA are aggravated by the climate variability and weather extremes (Aryal et al. 2020). The high extent and severity of soil degradation aggravate the PoU and malnutrition. The vulnerability of small landholders, with adverse effects on agro-

Table 1
Population and land area of countries of South Asia in 2022. Land use data are from World Bank (2023); population data are from the UN (2022).

Country	Population ($\times 10^6$)		Land area (10^3 km^2)	Land use (% of land area)		
	2022	2050		Cropland	Agricultural land	Forest land
Afghanistan	49	73	652.86	12.0	58.8	1.9
Bangladesh	173	204	147.63	61.5	76.1	14.5
Bhutan	0.79	0.90	38.39	2.5	13.5	71.4
India	1,429	1,668	3,287.26	52.3	60.2	24.3
Iran	89	103	1,640.00	9.6	29.0	6.8
Maldives	0.52	0.59	0.30	13.0	21.3	2.7
Nepal	31	35	147.18	14.7	28.7	41.6
Pakistan	240	366	770.9	40.1	47.6	4.8
Sri Lanka	21	22	65.61	22.2	45.5	34.2
South Asia	2,023	2,472	6,750.13	43.1	56.9	17.5

Table 2
Land use in South Asia in 2020 (FAOSTAT 2022).

Country	Cropland (10^6 ha)	Agricultural land (10^6 ha)	Forest land (10^6 ha)
Afghanistan	7.8	38.4	1.24
Bangladesh	9.1	11.2	2.14
Bhutan	0.10	0.52	2.74
India	171.9	197.9	79.88
Iran	15.7	47.6	11.15
Maldives	0.004	0.06	0.08
Nepal	2.2	4.22	6.15
Pakistan	30.9	36.70	3.70
Sri Lanka	1.5	2.99	2.24
South Asia	243.7	384.1	109.33

Notes: Calculated from table 1 using the data and total land area for each country (column 4) and multiplying with % cropland area (column 5), % agricultural land area (column 6), and % forest land area (column 7). The area for South Asia (last row) is calculated by summation of the respective land use area for each country.

decline in agronomic yield especially on rainfed agricultural lands. Additionally, irrigated land is also prone to secondary salinization, groundwater depletion, and numerous degradation processes (e.g., physical, chemical, biological, and ecological). Watershed community livelihood of small landholder farmers is also highly vulnerable to climate change in the Himalayas (Adhikari et al. 2020) and to flood-drought syndrome in the plains (Lal 2022).

Predominant soil degradation processes in SA include soil erosion by water (i.e., recurring floods) and wind (i.e., dust storms), secondary salinization, water logging, and groundwater depletion (table 4). Water erosion covers 21% of land area (46% of total degraded area), and it is the major cause of soil degradation in the region. The highest rate of soil erosion ($>9 \times 10^7 \text{ ha}$ [$2.2 \times 10^8 \text{ ac}$]) was recorded in the SA region (Wijesinghe and Park 2017). It is estimated that land degradation costs US\$10 billion to SA annually (Khor 2023), which may be a gross underestimate considering the magnitude and severity of the problem. In addition to commonly monitored processes, other degradation processes prevalent in SA, but not being monitored, include depletion of SOC content, nutrient imbalance, loss of soil biodiversity, decline in plant available water capacity, scalping of topsoil for brick making, urban encroachment, soil contamination and pollution by land disposal of industrial/urban wastes, and denudation of sloping land by indiscriminate deforestation. Further, SOC content in SA is declining because of the extractive farming practices of removal/burning of crop residues and accelerated soil erosion.

Despite its adverse impacts on human well-being and environmental quality, there is neither a well-planned study nor a long-term program to cooperatively undertake the assessment of soil degradation in SA. Yet, soil and ecological degradation are the common enemies of all countries. A study on malnutrition of children under age six in Iran indicated that 32% are underweight, 32% are of short stature, and 26% exhibit slimness (Motedayen et al. 2019). Mohseni et al. (2018) reported that in children under five in Iran, signs

agricultural productivity, is due to drought/heat waves and severity of runoff and accelerated erosion by water and wind. Severe depletion of SOC content, often as low as 0.1% to 0.5% in the root zone in comparison with an optimal range of 1.1% to 1.5% for most cropland soils, increases risks of low agronomic yields and poor nutritional quality of food produced. These interactive effects (soil degradation \times global warming \times small landholders and resources-poor farmers) may be an important driver of the increasing trend of PoU and malnutrition (21%) in SA.

SOIL AND ECOLOGICAL DEGRADATION IN SOUTH ASIA

The severe problem of soil degradation is a phenomenal tragedy affecting all countries of SA. Perpetual and continuous decline in soil functions is caused by land misuse and soil mismanagement. Decline in soil functions, because of anthropogenic activities (e.g., cultivation of steep land; unnecessary and excessive plowing; flood irrigation; removal and/or in-field burning of crop residues; unbalanced use of fertilizers such as applying nitrogen [N] but not phosphorus [P], potassium [K], and micronutrients; uncontrolled and excessive grazing), lead to loss of biological productivity and

Table 3
Per capita cropland, agricultural land, and forest land in South Asia, calculated from table 1.

Country	Cropland (ha person ⁻¹)			Agricultural land (ha person ⁻¹)		Forest land (ha person ⁻¹)	
	2011	2023	2050	2023	2050	2023	2050
Afghanistan	0.268	0.159	0.107	0.784	0.526	0.025	0.017
Bangladesh	0.0499	0.052	0.045	0.084	0.055	0.0123	0.010
Bhutan	0.131	0.122	0.107	0.660	0.580	3.470	3.046
India	0.129	0.120	0.103	0.138	0.119	0.056	0.048
Iran	0.233	0.176	0.152	0.530	0.461	0.125	0.108
Maldives	0.009	0.008	0.007	0.115	0.102	0.156	0.127
Nepal	0.0867	0.070	0.062	0.136	0.121	0.198	0.178
Pakistan	0.118	0.128	0.082	0.153	0.100	0.015	0.010
Sri Lanka	0.0575	0.071	0.068	0.142	0.136	0.107	0.102
South Asia	0.139	0.120	0.099	0.189	0.155	0.054	0.044

of wasting, stunting and underweight were 7.8%, 12.4%, and 10.5%, respectively. The Borgen project indicated that 34.9% of children in Bhutan are malnourished, and 12% are severely stunted. Problems of PoU and malnutrition are severe and persistent in India, Pakistan, Bangladesh, Nepal, Sri Lanka, and other regions of SA (FAO et al. 2023).

Severe soil degradation is the cause of human malnutrition globally (Lal 2009) and especially in SA. Both PoU and malnourishment in SA (table 5) can only be addressed by restoring and sustaining health of soils of croplands, agricultural lands, and forest lands. Soil and environmental degradation affect human health and well-being in SA as is the case in sub-Saharan Africa and elsewhere in developing countries.

COOPERATIVE PROGRAM TO RESTORE SOIL HEALTH IN SOUTH ASIA

Healthy soils are essential to human health and well-being because nutritious and safe food is grown only on a healthy soil. Yes, a healthy soil is the source of all the nourishment; it provides food to nourish our bodies, gives rise to knowledge that nourishes our minds, and shares beauty that nourishes our souls. Indeed, health of soil, plants, animals, people, ecosystems, and the planetary processes is one and indivisible.

Therefore, the urgency for restoration and sustainable management of health of soils of SA is more urgent now than ever before. Soil degradation, the common enemy among all nations of SA, must be addressed systematically on regional basis

Table 4
Extent and severity of soil degradation in South Asia.

Process of soil degradation	Land area affected (10 ⁶ ha)			
	South Asia		India	
	FAO and RAPA (1992)	FAO (1994)	ICAR and NAAS (2010)	Bhattacharyya et al. (2015)
Water erosion	111.0	81.7	73.3	94
Wind erosion	3,807	59.0	12.4	9
Soil fertility decline	—	42.4	5.7	16
Waterlogging	8.5	5.7	1.1	14
Salinization	17.7	28.5	5.4	6
Lowering of water table	—	19.8	—	7

because the underlying causes are factors and processes that cut across political, ethnic, cultural, and linguistic boundaries. Therefore, a long-term regional program must be developed and implemented using the same methods of assessment, establishment of critical properties, and prudent management of its fragile and excessively exploited ecosystems and its ability to cope with extreme climate events for sustainable management. Essential prerequisites for future improvements in SA depend on (1) prudent governance in each country, (2) peace and cooperation among countries, and (3) enabling a global context (Kakakhel 2012).

Existing intergovernment organizations are (1) the South Asian Association for Regional Cooperation, (2) the South Asia Cooperative Environment Program, and (3) the South Asia Regional Seas

Program. What is needed is a South Asian Association for Soil Health Restoration and Management, which must be specifically focused toward the following:

1. Creating political commitment to protection, restoration, and sustainable management of soil health
2. Promoting adaptation and mitigation of climate change through sequestration of C in terrestrial (green) and aquatic (blue) biomes
3. Monitoring and assessment of soil health of all biomes on five-year basis or more frequently (two years)
4. Rewarding farmers and land managers for adopting management practices which protect, nurture, and sustain soil health
5. Achieving soil degradation neutrality goals in each nation and each biome

Table 5

Prevalence of undernourishment in South Asia (adapted from FAO et al. [2022]).

Country	Undernourished (%)			Malnourished (million)		
	2000 to 2002	2004 to 2006	2017 to 2019	2000 to 2002	2004 to 2006	2017 to 2019
Afghanistan	47.8	36.2	29.9	10.4	9.3	11.1
Bangladesh	16.0	14.3	13.0	20.8	19.9	20.9
Bhutan	—	—	—	—	—	—
India	18.6	21.7	14.0	199.6	249.4	189.2
Iran	4.8	5.2	5.4	*	*	*
Maldives	—	—	—	—	—	—
Nepal	23.6	16.9	6.1	5.7	4.3	1.7
Pakistan	21.2	17.7	12.3	31.0	28.4	26.1
Sri Lanka	17.0	14.8	7.6	3.2	2.9	1.6

*35% of Iranians are malnourished.

- Strengthening training opportunities in measurement and monitoring of soil health and development of common data base
- Developing and strengthening human capital and cooperation between private and public sectors to facilitate translation of science into action
- Revising education curricula at all levels and incorporating the importance of soil health and the one-health concept at primary and secondary schools
- Promoting soil health and its stewardship through religious organizations (i.e., Bahai, Buddhism, Christianity, Hinduism, Islam, Jainism, Judaism, and Sikhism)
- Establishing a soil health award of SA for research, education, outreach, and advocacy among all stake holders (private sector, public sector, academicians, farm organization, communities, civic societies)

CONCLUSION

Soil degradation, and the attendant ecological degradation and accelerated global warming, are the common enemies of SA. It is the right time to assign high priority to addressing the common foe that cuts across political boundaries, affect human well-being, and jeopardize political instability. Just as countries of the European Union and different states of the United States, countries of SA must also focus on defeating the common challenge. Synergism, backed by political will and resolve to address these problems, can pave

the path to peace and prosperity for all at local, national, regional, and global levels. These countries have the trained human resources and natural capital. What is lacking is the political capital of willpower to work together and solve the issues of soil and ecological degradation and promote peace and prosperity for well-being of their citizens. The mission to restore degraded soils and ecoregions will be the foundation stone for building unity in SA and establishing an example for the world to follow as the Union of SA.

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