www.actiononclimate.today

Land and Soil management for sustainable agriculture in South Asia

POLICY BRIEF, NO. 34, 2017

The focus of agricultural policies has been more on modernization, commercialization and productivity increases, rather than enhancing the sustainability of agricultural growth.

Up to 20 per cent of Earth's land is already degraded adversely affecting billions of people's lives. In recognition of this problem, the General Assembly of the United Nations had declared 2015 as the *International Year of Soils (IYS)*. Furthermore, land and soil issues have been enshrined in Goal 15 of the United Nations' Sustainable Development Goals (SDGs) thus: *to protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification and halt and reverse land degradation and halt biodiversity loss.*

Goal 15's Target 3 states, more specifically: By 2030, combat desertification, restore degraded land and soil, including land affected by desertification, drought and floods and strive to achieve a land degradation neutral (LDN) world'.

Realizing the SDGs and their associated targets is not easy in the face of resource scarcity, changing climate and uncertainties in global markets and trade. This policy brief intends to provide focus and strategic options regarding land and soil management primarily for policy makers, development partners and farmers.

Land Resources

Land, the part of the Earth's surface that is not covered by water, is an essential natural resource for human beings which provides food, feed, fiber and shelter, not to mention the space in which human activities take place. The United Nations Convention to Combat Desertification (UNCCD) has defined land in a broader sense-- "the terrestrial bio-productive system that comprises soil, vegetation, other biota and the ecological processes that operate within the system." Literature provides several definitions of land implying a multitude of functions. These are: productive function through which food and biomass are produced, resource function that makes it act as biological habitats and provides space for human settlements and source of materials and minerals, regulatory function to regulate the climate including hydrological regulation, control function for waste and pollution control.

Land Degradation in South Asia

Land degradation refers to any change in the quality of land and bio-physical environment or ecosystem functions resulting in temporary or permanent decline in its productive potentials. The term is synonymous with *desertification* in dry and dry-humid regions. Degradation can take various forms including the loss of ecosystem resilience, biodiversity and bio economic productivity of arable land, pasture and forest. Land degradation occurs naturally, but gets accelerated by anthropogenic factors and unsustainable human practices.

South Asia covers about 5.1 million square kilometers of land area of which about 39 per cent is arable. Apart from the islands, it includes three topographical regions: (a) the Himalaya, Karakorum and Hindu Kush Mountain ranges and their southern slopes, (b) The Indus and the Indo-Gangetic Plain and (c) Deccan Plateau and other uplands. In South Asia about 90 per cent of the arable land belongs to India (79.72 percent) and Pakistan (10.25 per cent) together. With only 3.4 per cent of the global land surface and one quarter of the world population (1.75 billion), this region is at a very high risk of land and soil degradation. Soil erosion is the most important form of land degradation in South Asia. About 25 per cent of areas under crops and pasture are degraded through erosion caused by water. India's land vulnerable to degradation was estimated to be 81 per cent (Box 1), the highest in the region. For Bangladesh, Sri Lanka, Pakistan, Nepal and Bhutan, the vulnerability to degradation is estimated to be 63, 53, 39, 21, and three per cent of their land respectively. Land and soil degradation is a general problem of the region but serious problems are specific to certain locations and sub regions, identified as degradation hotspots across South Asia (Table 1).

Major Drivers of Land Degradation

- *Soil Erosion:* Soil erosion is caused by water and wind and is the major form of land degradation in sloping lands and dry areas. Soil erosion is a serious problem for agriculture and food production in the hills and mountain regions of South Asian countries (Box 2).

- *Waterlogging:* It is a major concern in low lying plains and river-fed irrigation systems. The rise in groundwater levels close to the soil surface and inadequate drainage in irrigation systems are the main reasons for waterlogging. This deteriorates the soil structure and oxygen deficiency occurs at the crop-root zone.

- *Salinization:* In marginal land and poorly managed irrigated areas, salt accumulation often occurs or sodium levels may increase leading to soil and land degradation.

- *Sedimentation:* Sedimentation occurs through flooding where fertile land is buried under infertile or less fertile sediments, sands or stones particularly near river systems. Winds in dry, arid and semi-arid areas inundate fertile land with sand.

- *Overgrazing and Loss of Vegetative Cover:* Increased demand for animal protein due to an increasing number of wealthy people has led to an increase

Box 1 Soil Degradation in India

India, with about 79 per cent of the arable land area of South Asia, sees soil degradation in 147 million hectares, mostly from water and wind erosion, acidification, flooding and salinity. This is extremely serious as India supports 18 per cent of the world's human population and 15 per cent of the livestock population in spite of having only 2.4 per cent of the global land area.

Source: Bhattacharyya et al, 2015

in the livestock population. This may lead to overgrazing resulting in the loss of vegetation cover in the absence of adequate rangelands. Fodder collection from forests leads to increased deforestation thus accelerating land degradation. Overgrazing prevents regrowth of plants leading to a loss of the green cover, low soil infiltration, accelerated runoff and soil erosion.

- *Desertification:* Desertification can occur naturally in arid, semi-arid and dry-humid areas or induced by human interventions. This is a prime concern in the dry areas of India and Pakistan. With little vegetative cover and high moisture stress in the soil, agricultural farming and maintaining livelihoods becomes extremely difficult.

- *Over-cultivation and Nutrient Depletion:* Intensification of agriculture and mono cropping are usually associated with soil-nutrient mining (extracting more nutrients than putting in). In conventional agriculture, crop residues are removed from the fields and inadequate organic manures are added to the soil. This results in the loss of nutrient and organic matter from the soils. Most of the cultivated soils in South Asia suffer from a negative balance of major nutrients, not to mention acidification and a decline of organic matter.

Box 2 Land Degradation in South Asia

As India has the highest amount of land degradation other countries in the region have also been badly affected. It is estimated that nearly one-third of land in Sri Lanka is subject to soil erosion and one-fourth of land in Pakistan is subject to water and wind erosion. In parts of Northern India and Bangladesh soils have become acidified and salinized. The steep terrains of Nepal are susceptible to soil erosion and landslides.

Source: UNEP Environmental Indicators South Asia

Table 1 Hotspots of Land Degradation in South Asian Countries

Degradation Types	Hotspots
Nutrient Depletion	Mid altitude of Nepal, North India
Salinization	Indus River Basin, Gangetic Basin and Southern Coast lines of Sri Lanka
Water Erosion	Himalaya Foothills, Riverbank Erosion in the Major Floodplains such as Ganges, Brahmaputra, Jamuna, Tista and Meghna Rivers
Wind Erosion	Western Rajasthan, Coastal Regions of India and Dry Region of Pakistan
Agrochemical pollution	Pakistan (heavy use of agrochemicals)

Source: Sarkar et al (ed), 2011

- *Inappropriate Land Use:* For decades, intensive cultivation of arable lands has led to land degradation. Advanced technologies in the fields of high yielding variety (HYV) seeds, chemical fertilizers, irrigation, pesticide application and mechanization are the main culprits. The frequent disturbance of soil brought on by over-cultivation has encouraged soil erosion and nutrient depletion. An increased use of fertilizers and pesticides have led to soil acidification and environmental pollution. Incentives to farmers to meet the

www.farmerseekingroots.com

government's national food self-sufficiency goal have encouraged over-cultivation and misuse of even marginal lands. Fertile and good quality lands have also been increasingly taken over for non-agricultural purposes such as urban expansion, industrialization, mining and quarrying. All of these are sources of land degradation. Lack of land policies and good governance has also contributed significantly to land degradation in South Asia.

Soil Fertility in South Asia

The productivity of land most often depends on the fertility of the soil, which is known to be declining, particularly in tropical areas of South Asia. Soil is the thin layer of organic and inorganic material that covers land. Soil fertility can be measured in terms of compounds and ions but it does not give much idea about crop productivity. A fertile soil may not necessarily be a productive soil and all productive soils are not fertile. The productivity of soil is its capacity to produce output, commonly measured in yield. The productivity concept, therefore, relates to the combined effects of all factors necessary for plant growth.

Soil is fundamental to life on Earth, but it is a finite resource and susceptible to degradation. Intensive cropping results in higher nutrient removal from the soil (usually NPK, sulphur, boron and zinc). This is the general scenario in most of South Asia. In Bangladesh, it was found that two rice crops with 10 metric tons per hectare annual yield removed nearly 350 kg of nutrients per hectare from the soil. India, Nepal, Pakistan and Sri Lanka have witnessed multiple nutrient deficiencies in different degrees of severity, mainly due to inadequate and unbalanced fertilizer application. Phosphorus and potassium depletions were found mostly in rice-rice, rice-vegetable, rice-potato and other cereal-based cropping sequences.

Secondary macronutrients (calcium, magnesium and sulphur) have become deficient in acidic sandy soils that are already low in organic matter. Regarding micronutrient deficiency in most South Asian soils, there is boron deficiency in cauliflower, papaya, mustard and wheat, molybdenum deficiency in cabbage and tomato and zinc deficiency in rice, maize, tomato and onion are common. Copper can be a limiting factor on some organic soils, whereas high pH levels can limit the availability of iron, manganese and zinc.

Organic matter constitutes only a small fraction (up to 5% by weight) of the soil but it has a profound influence in fertility maintenance. It exerts major impacts on physico-chemical and biological properties of soils. Ideally, organic matter should be between four to five per cent, but most soils in South Asia contain far below those levels. A study found less than two per cent organic matter content in the soils of Bangladesh and Nepal; in some intensively cultivated areas, it was below one per cent. The main reasons reported were continuous removal of crop biomass, continuous use of chemical fertilizers without commensurate application of compost and other organic fertilizers and climate change impacts on soil properties.

The rise in the mean temperature due to greenhouse gas emissions may have various impacts on soil fertility and mineral nutrition of crops. Its effects can be on soil erosion rates, organic carbon levels, the moisture regime, build-up of salts, microbial activities and root-growth of plant systems. The decline in soil quality, particularly the loss of soil carbon, adversely affects nutrient-use efficiency and crop yields exacerbating food insecurity in vulnerable regions. It is estimated that cultivated soils worldwide have lost between 50 to 70 per cent of their original carbon reserves.

To Tackle Land and Soil Degradation

There are a number of preventive methods to arrest land degradation, the most effective of which are discussed below:

- *Prevent Soil Erosion:* Soil erosion is the major cause of land degradation, loss of soil fertility and reduced crop productivity, particularly in the sloping lands and fragile areas of South Asia. Soil erosion caused by the summer monsoon in the hills and mountains is a serious problem. There are mainly two methods in practice to control soil erosion- agronomic and mechanical.

  a) Agronomic Method of Soil Conservation: The main principle of the agronomic practice is keeping the soil covered and maintaining minimum tillage. This dramatically increases the infiltration rate and decreases the quantity of rainwater that runs off the soil surface, thus preventing floods and soil erosion. Contour farming, strip cropping, grass barrier strips, mulching and agro forestry in more inclined slopes and light textured soils are some of the effective measures to control soil erosion.
  b) Mechanical or Engineering Method: In this method, terraces are constructed by digging a trench and throwing soil uphill to make an embankment to retain or drain excessive water. To check gully erosion, small stream check dams can be built with gabions and stone walls. Embankment can be built against gully erosion by making a trash wall or creating a ridge of plants such as sisal.

- *Prevent Waterlogging:* Poor water management can result waterlogging. In irrigated land, canal seepage is a main source of waterlogging, which can be controlled by lining the canals, increasing the gradient of those canals and regulating canal discharge. Applying only the required amount of water and adopting more efficient irrigation methods, such as sprinkler and drip irrigation, can be good options too. Similarly, control of inflow from other water bodies and runoff from higher ground to lower fields is another intervention against waterlogging. An efficient drainage system is essential for the fast disposal of heavy downpour or excess irrigation. Planting trees such as eucalyptus, which can take in huge amounts of water, and crops that have high rate of evapotranspiration can serve as a biological drainage system for low lying areas.

- *Reclaim Saline and Sodic Soils:* Soluble salts adversely affecting the growth of most crops and vegetation can be removed from the root zone. The common methods of reclamation of saline soils are scraping, flushing and leaching. Scraping the salts that have accumulated on the soil surface by mechanical means is the least effective method. Flushing or washing away the accumulation from the soil surface also has shown limited success. The most effective method to remove salts from the soil surface is through leaching. Leaching is done by ponding fresh water on the soil surface and allowing infiltration into the soils from the reclaimed area. To remove exchangeable sodium ions from sodic soils requires the application of chemical amendments. The most common amendment materials are gypsum, calcium chloride, acid or acid forming compounds such as sulphuric acid, iron and aluminum sulphate, lime-sulphur, pyrite and calcium salts of low solubility such as ground limestone.

- *Manage Overgrazing and Land Degradation:* Overgrazing is the result of overstocking, implying a situation where there is more livestock than land available for grazing. Livestock occupies the largest area of land on Earth, more than twice the area under crops. In South Asia, for example, India has a livestock population of around 15 per cent of the global population. They graze on a tiny 0.5 per cent portion of the global pasture land. It means that around 42 animals graze per hectare as against the threshold of five animals for that amount of land. This shows the need for downsizing the number of animals per hectare of pasture. Another option is to switch to small ruminants and poultry keeping, which are more resource efficient than cattle. Zero grazing or stall feeding, particularly suitable for improved livestock breeds, is another strategy.

To maintain soil health the balance of nutrients must be made positive by adding organic and inorganic fertilizers in combination, conserving moisture and preventing nutrient losses.

- *Prevent Desertification:* Climate variability and unsustainable human practices are two major reasons for desertification especially of dry lands. Human activities like over-cultivation, deforestation, overgrazing and poorly drained irrigation systems that promote salt build-up in the soils aggravate the problem. A combination of policy, sustainable livelihood practices and local community level efforts is needed to prevent, stop or reverse desertification. Organizing people and raising awareness about desertification, adopting sustainable agricultural practices, conservation and sustainable use of water resources, planting indigenous trees and shrubs, use of alternative and renewable energy and managing livestock and preventing overgrazing also help.

Integrated Soil Nutrient Management (ISNM)

ISNM is known by different names. The key is in knowing the nutrient budget or balance, which is the sum of nutrient gain minus the sum of nutrient loss in the soil pool. Making the best use of native soil nutrients, locally available sources of nutrients (crop residues, compost, farm yard manure and green manuring and other bio fertilizers) and chemical fertilizers all contribute towards that end. To maintain soil health the balance of nutrients must be made positive by adding organic and inorganic fertilizers in combination, conserving moisture and preventing nutrient losses.

Realizing the SDGs and their associated targets is not easy in the face of resource scarcity, changing climate and uncertainties in global markets and trade.

ISNM has the following components:

- *Building and maintaining native soil nutrients* can be achieved by conserving existing nutrient resources against soil erosion, leaching and gaseous losses. This is accompanied by rebuilding the natural nutrient cycle in the system. Getting back crop residues, compost FYM are key to enhance nutrient cycle in the farming systems.

- *Enhancing legume based cropping sequence* promotes biological nitrogen fixation and increases biological activities in the soils. There are several legume crops, shrubs and trees that can transfer nitrogen from the atmosphere when the nitrogen level in the soil falls short. In addition, nutrients can be added through bio-fertilizers (using various strains of bacteria, algae and fungi as microbial inoculants to fix nitrogen), vermicomposting (in which earthworm converts wastes and residues into compost) and green manuring (in which both legume and non-legume plants are ploughed down into the soils at their young stage).

- *Fertilizer-use efficiency can be improved* through balanced and site specific use according to the soil's nutrient supplying capacity. Fertilizers are often inefficiently used resulting in only a small fraction of the applied nutrients becoming available to the crops. Studies show that yield response to fertilizers in many production systems has been declining since the 1980s, worldwide. Nitrogen use efficiency, for example, in cereal production decreased from 80 per cent to 30 per cent. Correct fertilizer ratio and optimal quantity, using correct methods and timing all play important roles. South Asia, the second largest fertilizer consuming region in the world, has a nutrient ratio of 6.5:2.4:1.1 for nitrogen, phosphorus and potash application (2012), whereas the ideal ratio is 4:2:1. Only two crops (rice and wheat) consume more than 55 per cent of the fertilizers, while maize, millet, sorghum, etc. that are important to smallholders' food security get far less. In South Asia the average use of fertilizer is about 150 kg per hectare (2013), which is higher than the world average of 120 kg, but there is also a huge variability among countries ranging from as low as 12 kg in Afghanistan to over 200 kg per hectare in Bangladesh and Maldives.

- *Soil Carbon Sequestration:* To enhance soil organic matter and to reduce greenhouse gas emissions, carbon sequestration is the most important solution. It involves transferring atmospheric carbon dioxide into the soil carbon pool. Implementation of integrated soil fertility management, leaving enough crop residues in the fields, mulch and plant cover year-round, crop rotation, use of soil amendments and reduced tillage help that happen. Shifting land use to perennial or deep-rooted crop and agro forestry can significantly increase the soil's carbon stock.

- *Fertilizer Use based on Soil-Test Values:* In most of South Asia there is a blanket recommendation for fertilizer use usually made without site specific crop response and soil test. This is not rational as it does not account for local nutrient availability, farmer's yield goal, crop to be grown, soil type and its moisture regime. Farmer's input-use practices and soil management knowledge are considered to be the efficiency factor influencing the amount of nutrient application. Higher the efficiency, lower the quantity of nutrient use and vice versa. Although site specific fertilizer prescription is resource intensive, blanket recommendation is even more undesirable and costlier to farmers, especially if higher dosages are applied on soils which already have high to very high levels of nutrients. To avoid such wasteful use of inputs, including fertilizers, precision farming is gaining popularity in developed countries. It can also be adopted in South Asia for a sustainable intensification of agriculture.

- *Precision Agriculture:* Precision agriculture or satellite farming is an approach that uses information technology to ensure that crops and soils receive exactly the amount of inputs they require. The goal of precision agriculture in this context is to prevent wasteful use of inputs and ensure sustainability of farming systems. This method utilizes the global positioning system (GPS) and GPS computer guided farm machineries such as tractors and harvesters. It also employs electromagnetic soil mapping, aerial imagery (through satellites and robotic drones), specialized equipment, software and services for data processing and integration. Precision farming can be immensely useful in site specific nutrient management.

- *Nano Technology in Fertilizer Use:* In conventional fertilizer application, a very small amount of nutrient reaches the targeted site due to run off, drift, leaching, evaporation, hydrolysis and photolytic and microbial degradation. It is estimated that about 40-70 per cent nitrogen, 80-90 per cent phosphorus and 50-90 per cent potassium content of applied fertilizers are lost to the environment. This is a huge loss of nutrients. Nano-fertilizer can precisely take nutrients to the targeted sites, whereby it can enhance the nutrient use efficiency and reduce waste and environmental pollution. A nano-particle is one billionth part of a meter and the use of this technology has an incredible potential to revolutionize many aspects of farming. However, the health and environmental risks associated with their application are yet to be determined.

> The focus of agricultural policies has been more on modernization, commercialization and productivity increases, rather than enhancing the sustainability of agricultural growth.

Create Enabling Environment through Policy and Legal Reform

Without appropriate policies and enabling environment, an effective land and soil management regime for sustainable intensification of agriculture is difficult to come by. There are several agricultural policies for the advancement of agricultural growth in the region. However, their focus has been more on modernization, commercialization and productivity increases rather than enhancing the sustainability of the growth. Steps are, therefore, needed to carefully review, reform and develop policies (on taxes, subsidies, price incentives, laws and provision of technical services) that support sustainable land management and integrated soil fertility management. Policies must create an environment whereby farmers are motivated to work in their land for higher production while conserving the soil and land resources. Without secure rights to land, many small farmers are not even willing to invest in their farms. The land tenure issue and access to land must be resolved through appropriate land reform policies.

The existing fertilizer subsidy policies in most South Asian countries are not effective to promote sustainability. Some countries give out huge subsidies in fertilizers encouraging farmers to overuse them to


www.businessansar.com

lansasouthasia.org

the extent of polluting the environment. Others are using much less because of low or no subsidies at all, thus causing widespread soil nutrient mining. In any case, most subsidies are not well targeted. It is therefore necessary to review the national policies to ensure that fertilizer inputs are properly used and farmers have enough incentives to invest in good agricultural practices and soil and water conservation. Policies are needed to ensure an easy access to soil and fertilizer testing facilities for site-specific fertilizer application. Switching to sustainable intensification of agriculture requires effective agricultural extension, research, education and capacity development. More investment is also needed to improve rural infrastructures, road connectivity and market access to farmers and traders. ■

References

Bhattacharyya, R., B.N. Ghosh, P.K. Mishra, B. Mandal, C.S. Rao, D. Sarkar, K. Das, K.S. Anil, M. Lalitha, K. M. Hati and A.J. Franzluebbers. 2015. "Soil Degradation in India: Challenges and Potential Solutions". *Sustainability* July: 3538-3570. www.mdpi.com/journal/sustainability.

Cook, S., C. Henderson, M. Kharel, A. Begum, A. Rob and A. Piya. 2016. *Collaborative Actions on Soil Fertility in South Asia: Experiences from Bangladesh and Nepal*. Working Paper. www.iied.org.

Debtanu, B., S.C. Mandal, P. Bhattacharjee and N. Ray. 2013. "Land Degradation, Management and Environmental Benefits of Management in Reference to Agriculture and Aquaculture". *Environment and Ecology* 31 (2C): 1095-1103.

EU. 2016. *EU Global Action on Sustainable Land Management*. Brussels: European Union.

FAO, 2011; *Save and Grow.* Rome: Food and Agriculture Organization.

Hassan AWR, 2016; *Bangladesh National Conservation Strategy-Crop Agriculture.* Dhaka: Bangladesh Forest Department.

Lal, R. 2009. "Potential for Soil Carbon Sequestration." In *Agriculture and Climate Change: An Agenda for Negotiation in Copenhagen*. Washington DC: International Food policy Research Institute.

Montpellier Panel Report. 2013. *Sustainable Intensification: A New Paradigm for African Agriculture.* London: Imperial College London and Agriculture for Impact.

Sarkar, D., A.K. Azad, S. K. Sing, and N. Akter (ed.). 2011. *Strategies for Arresting Land Degradation in South Asian Countries.* Dhaka: SAARC Agriculture Center.

SAEO. 2014. *South Asia Environment Outlook 2014.* SAARC/ UNEP/Development Alternative.

Schwilch, G., H.P. Liniger, and A. Lannen. 2015. *Saving Soils at Degradation Frontlines: Sustainable Land Management in Drylands.* CDE Policy Brief. Bern: Center for Development and Environment (CDE), University of Bern.

Solanki, P., A. Bhargave, H.R. Chhipa, N. Jain and J. Panwar: "Nano Fertilizers and their Smart Delivery System." In *Nanotechnologies in Food and Agriculture*, edited by M. Rai, C. Ribeiro, L. Mattoso and N. Duran. Springer, Cham.

World Bank. 2006a. *Integrated Nutrient Management for Sustaining Soil Productivity.* Washington DC: The World Bank.

World Bank. 2006b. *Sustainable Land Management*. Washington DC: The World Bank.

sawtee

www.sawtee.org

P.O. Box: 19366, Tukucha Marg
Baluwatar, Kathmandu, Nepal
Tel: +977-1-4424360/4444438
Fax: +977-1-4444570, E-mail: sawtee@sawtee.org
Design: Bipendra Ghimire
Printed at Orange Press, Lalitpur

South Asia Watch on Trade, Economics and Environment (SAWTEE) is a regional network that operates through its secretariat in Kathmandu and 11 member institutions from five South Asian countries, namely Bangladesh, India, Nepal, Pakistan and Sri Lanka. The overall objective of SAWTEE is to build the capacity of concerned stakeholders in South Asia in the context of liberalization and globalization.