Chapter 5
Soil Degradation Problems and Foreseen Solutions in Uzbekistan

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Abstract Soil erosion and salinity are long-standing afflictions of Uzbekistan. Regional climate change, already evident, is likely to exacerbate droughts and high summer temperatures; the future rainfall regime is unknown. All these hazards will increase the risk of land degradation. The Aral Sea has been declared a *zone of environmental innovation and technology* but, beyond sowing halophytes in its dry bed, we are a long way from restoration. New and different ways have to be found to combat these challenges including science-based crop rotation taking into account soil characteristics; sustainable farming systems adapted to the harsh landscape; widespread adoption of agro-ecotechnology, biotechnology and information technology in soil conservation and land use planning; and effective ways to combat salinization, erosion, depletion of soil organic matter, and compaction. All need a sound theoretical base. Innovations under trial include soil improvement with a range of vegetable crops and legumes, application of various composts including worm compost from household waste and biogas production residue, microbiological preparations, and systematic reclamation of gypsum soils.

Keywords Climate change · Soil erosion · Salinity · Aral Sea · Policy and technical responses

Introduction

Uzbekistan is one of the big states of Central Asia with more than 33 million people, extensive irrigated agriculture and developing industries. The diverse landscape ranges from high mountains, foothills, and plains, to depressions. The plains include the Ustyurt Plateau and the Aral lowland in the northwest, most of the Kyzyl Kum

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Desert and the adjoining steppes that grade into the foothills. In the east are mountain ranges enfolding the valleys of Ferghana, Zerafshan, Kitab-Shakhrisabz, and Sherabad-Surkhandarya. The continental climate is characterized by big daily and seasonal temperature fluctuations; hot, dry summers; rains in autumn; and unstable winter weather. Except in the mountains and foothills, it is arid so there are relict salt deposits as well as modern salt accumulations—and both of these have often been remobilized by irrigation (Juliev et al. 2017). Frost, heavy rains, hail, and strong winds can occur everywhere. The average wind speed across the plains is 3–4 m/s but gusts of 6–10 m/s raise dust storms on 10–30 days a year on flat land, up to 50 days on the Karshi Steppe and lower reaches of the Amu Darya, and up to 64 days in the Muynak steppe-desert in the Aral Sea region; winds in excess of 15 m/s that prevent sheep grazing occur up to 11 days a year. Local east winds in the foothills are known as *Bekabad* and *Kokand*; and hot, dry winds from the mountains, known as the *Garmsil* and *Afghan*, bring dust and sand storms (Belolipov et al. 2013).

Land Degradation

Geography makes the country vulnerable to land degradation that threatens the whole economy, agriculture in particular, and the living standards of the people. Land degradation is of long standing. It takes many forms: waterlogging and secondary salinization of irrigated land, pasture degradation and deflation in rangelands, deforestation and erosion by water in the mountains and foothills, compaction and depletion of soil organic matter in cultivated land everywhere, pollution by agrochemicals and industrial emissions, and the disastrous desertification of the Aral Sea (Aw-Hassan et al. 2016; Dubovyk et al. 2013; Egamberdiyeva et al. 2007; Gintzburger 2003; Nurbekov et al. 2016; Shaumarov et al. 2012; Shirokova and Morozov 2006; Strikeleva et al. 2018).

The many faces of land degradation are a consequence of interactions of physical, biological, political, social, cultural, and economic factors; some predetermined by nature but all of them exacerbated by failures of policy and planning, irrational management, and a lack of awareness and involvement of society at large (Nurbekov et al. 2016). Natural hazards include drought and floods, forest and steppe fires, and winds that exploit any weakness in the soil cover to bring deflation, dust, and salt storms. Long slopes promote water erosion, mudflows, and landslides (Juliev et al. 2019); depressions harbour waterlogging and salinization (Vogel et al. 2018); topography drives local winds; attributes of the parent rock determine subsidence and karst phenomena, soil texture, crusting, salinity, and predisposition to wind erosion; and the degree of buffering determines resistance to various toxic substances (Merritt et al. 2003). But there can be no dispute that mismanagement has played its part in the loss of soil organic matter and nutrients; soil contamination with pesticides; violation of stocking limits leading to bare ground and destruction of the soil structure that opens the door to deflation and sand encroachment over fertile land; deforestation leaving mountain slopes open to erosion (Gintzburger 2003; Mueller et al. 2014);

irrigation with inadequate drainage causing waterlogging and salinity, and reliance on big doses of mineral fertilizers and pesticides on cotton fields contaminates both land and water (Durán Zuazo and Rodríguez Pleguezuelo 2008).

The hazard of soil erosion is common to drylands everywhere. In Uzbekistan, out of the total area of 26 million ha of farmland, less than 6% *is not* subject to erosion. More than 4.7 million ha suffers from erosion by water (Strikeleva et al. 2018). Of the 3.7 million ha of irrigated land, 2.9 million ha (75%) is eroded to some degree, annual soil removal can reach 100–500 t/ha, and the annual loss of humus 500–800 kg/ha is equivalent to 100–120 kgN and 75–100 kgP/ha (Nurbekov et al. 2016; Shaumarov et al. 2012). Salinity affects 65% of irrigated soils and increased groundwater discharge brings secondary salinization, commonly with the formation of gypsum soils (Krasilnikov et al. 2016).

The Aral Sea

The Aral Sea is a glaring example of reckless exploitation of land and water resources. It was one of the world's largest enclosed water bodies, covering 68.9 km^2, with a volume of 1083 km^3 and maximum depth of 68 m, receiving an average annual input of 50–55 km^3 from the Syr Darya and Amu Darya rivers (Micklin 2014a, b). It moderated the regional climate, the wellbeing of the population, agricultural production, and regional ecology (White 2014), and it supported a valuable fishery. Large-scale construction of irrigation canals began in Central Asia in the 1930s and intensified in the 1950s. The irrigated area increased from 4.5 million ha in 1960 to 9.1 million ha, and annual water demand increased from 60 to 120 km^3, of which 90% was consumed by irrigation. In less than half a century, the inflow to the Aral Sea decreased four or five-fold; the volume of water in the sea decreased 15-fold, and its salinity has increased to 125–300 g/l—more than 10 times the average salinity of the oceans (Xenarios et al. 2019).

The dry sea bed, the Aralkum Desert, now comprises more than 5.5 million ha of salt flats subject to frequent dust storms that annually spread 100 million tons of dust and salt over a distance of 300 km or more (Krivinogov 2014). The number of days with temperatures above 40 °C has doubled and wintertime temperatures are now often below −30 °C. The catastrophe engulfed more than half of the gene pool; the biological productivity of the whole region decreased ten-fold. From the Red Book, the Turanian tiger, Asian cheetah, Ustyurt sheep, and striped hyena are lost; the saigak was on the verge of extinction; and the Red Book has been supplemented by 11 species of fish, 12 mammals, 26 species of birds, and 11 species of plants (Matsui et al. 2017).

In response, however belated, the Aral Sea has been declared a *zone of environmental innovation and technology*. It remains a focus of attention for international organizations, politicians, and experts from around the world (Wheeler 2018). A state program to improve conditions and quality of life in the Aral Sea region from 2017 to 2021 was approved with a budget of 8.4 trillion sum ($US 81 billion). At the same time, Uzbekistan initiated a multi-partner trust fund for human security for the Aral Sea region, which received UN support. The Government has promulgated a National Environmental Health Action Plan, National Strategy and Action Plan for the Conservation of Biological Diversity, and National Action Program to Combat Drought and Desertification (Yang 2011). In the period 2013–2017, more than 500 projects have been undertaken—in particular, aerial seeding of 350 thousand ha on the dry seabed with saxaul *(Haloxylon ammodendron)* and other salt-tolerant plants to stabilize the soil. A related program has improved 2.2 million ha of irrigated land, reducing by 10% the area of land with critical groundwater levels.

Climate Change

Climate change isn't a problem for the future: *it is a problem now*. And agricultural strategy should take account of it (Lioubimtseva and Henebry 2009). Three-quarters of the country is desert occupied by hard-to-manage grey-brown soils, takyrs, sand, and salt marsh. The remaining quarter, in the high-altitude zone of dark grey and brown soils, meadow steppe and hydromorphic soils is now at greater risk of frosts and drought as the snow melts sooner year on year. In the face increasing aridity, soil and water resources are limited and their current condition is alarming; over the past 30–50 years, the soil organic matter and nutrient content has declined; salinity, soil erosion, and pollution by heavy metals, fluorides, and agrochemicals have all worsened (Mustaeva and Kartayeva 2019).

Across Central Asia, regional climate change means more extreme weather events, changes in the rainfall regime, and further land degradation. By 2050, depending on the predictive model, the region may experience an increase in mean annual temperature of 1.9–2.4 °C with the greatest warming in winter and spring; and mean annual rainfall may increase by 15–18%, mostly through summer rains, or it may not. What is certain is more risk for agriculture with its dependence on already insufficient water resources, most particularly in the Aral Sea Basin where the water deficit will increase from 2 km^3 (in 2005) to 11–13 km^3 in 2050. By way of compensation, a longer growing season may make it possible to grow new crops (Haag et al. 2019; Reyer et al. 2017).

Priorities for Land Use and Soil Science

Urgent and far-reaching action is needed to combat land degradation and establish more sustainable land use across the country. What is missing? What else do we need to know? These are good questions and our answer is Plenty, both practical and theoretical. Necessary practical improvements in agronomy, soil science, and technology include:

- Effective methods to combat salinization, erosion, depletion of humus, and compaction
- Sustainable farming systems adapted to our harsh landscape
- Introduction of science-based crop rotations according to the best predecessors for each individual crop, taking into account soil characteristics
- Widespread adoption of agro-ecotechnology, biotechnology and information technology in land use planning and soil protection.

All these need to be underpinned by better theory, so we also need:

- Investigation of the processes of transfer of substances and energy in the upper layers of the soil
- Theoretical foundations and effective technologies for reclamation of dryland, saline, gypsum and eroded soils
- Improved soil classification
- Inclusion of agricultural science in the training for the agricultural sector, and integration of higher education, agricultural science, and production
- Promotion of soil science, drawing public attention to the problems of soil and land use and protection, and international cooperation to broaden and deepen our knowledge.

Innovative Methods and Technologies on the Test Bed

- *Improving the fertility of degraded soils by growing vegetables and legumes.* The standard forms of soya, chickpea, and asparagus beans (*Vigna unguiculata* ssp. *sesquipedalis*), used as the main crop or as a cover crop, improve the soil's chemical and physical properties, and increase its biological activity. Winter legumes, in particular, enrich the soil with nitrogen, other nutrients, and biologically active substances, increase microbiological and enzymatic activity, and improve soil permeability and the wet strength of soil aggregates.
- *Improving the fertility of degraded soils by enriching them with organic matter.* Soil fertility is enhanced by diverse crop rotations including perennials and cover crops, combined with 15–20 t/ha composted crop residues applied at the time of autumn ploughing. Biogas-production digestate is first-class organic fertilizer that greatly reduces the need for mineral fertilizers.
- *Increasing the fertility of degraded rangeland.* Seed germination and plant survival, soil health and pasture productivity have been improved by a suite of agro-eco-biotechnologies: microbiological fertilizers, hydrogels, nano-adapters, pelleting, and electrical treatment of plants with high forage value.
- *Improving the fertility of rainfed croplands.* The use of hydrogels, biological preparations, composts, new types of mineral fertilizers, and foliar feeding of grain crops improve grain quality and increasing productivity by optimum use of soil moisture.

- *Improving fertility and preventing secondary salinization on slightly saline irrigated lands.* Measures include autumn soil leaching, increased rates of organic fertilizers and the use of plant residues, crop diversification including legumes. The need for soil flushing is much reduced and the accumulation of organic matter makes for fertile, well-structured soils.
- *Reclamation of desert soils contaminated with oil and oil products* by bioremediation and phytomeliorants over 5–7 years, followed by restoration of fertility.
- *Reclamation of infertile soils with organic and mineral fertilizers based on secondary resources.* Less-costly organic and natural mineral fertilizers derived from glauconite, bentonite, and low-grade phosphorites by vermicomposting with manure, as well as bio-humus with mineral additives.
- *Vermicompost from solid household waste (SHW).* Composting organic waste and other materials using local lines of earthworms to obtain an economical organic fertilizer containing the basic nutrients and microelements. Bio-organic fertilizer enriches the soil with organic matter, macro- and micro-nutrients, increases biological activity, and improves soil's water-holding properties.
- *Phytomelioration: Liquorice (Glycyrrhiza glabra L)* grows for more than ten years and, at the end of the rotation, the rhizomes are harvested and the field is prepared for another crop. It enriches the soil with organic matter and increases water-resistant aggregates by 70–80%, reduces bulk density to optimum values of 1.3–1.4 g/cm^3 and its roots, penetrating to a depth of 3.5–4 m, lower the saline groundwater. *Indigo (Indigofera tinctoria)* is in demand in the world market. Studies under the ZEF/UNESCO project Bonn/Urgench State University have shown that it can be grown successfully on saline degraded land. Symbiotic root-nodulating bacteria fix nitrogen from the air and enrich the soil; as well as yielding the natural dye *indigo*, the crop makes good green fertilizer.
- *Nano-irrigation and drainage techniques* improving the ecological resistance of plants to extreme environmental conditions using small-volume biological preparations that increase germination energy and biological productivity of crops.
- *Management of saline and gypsum soils*. Measures include deep soil loosening, maintenance of collector drains, flushing the root zone, balanced plant nutrition; crop rotation of cotton (April–October)—winter wheat (October–June)—legumes (July–October)—grass under cover crops (October–March), soil enrichment with plant residues after harvest, timely inter-row cultivation; and biological methods of plant protection, fertilizers, and adaptogens.
- *Issuance of an agro-reclamation soil passport* of a farmer's field that includes complete information about soil, reclamation, and climatic conditions (topography, nutrients, salinization, basic soil properties, etc.) and which supports decision-making on effective agricultural practices.

Conclusion

The priorities for soil science in the context of adaptation of agriculture to climate change are:

- Optimizing the biological activity of soils under various soil and climatic conditions and farming systems, including further development and adoption of agro-eco-technologies
- Theoretical foundations and effective ways to combat salinization, erosion, humus decline, crusting, and pollution with heavy metals, fluorides, and agrochemicals
- Interaction between fertilizer efficiency, environmental factors, the specific needs of individual crops, and ways of applying fertilizer
- Science-based crop rotation, alternation, and placement of crops
- Environmentally-friendly farming systems adapted to particular landscapes
- Carbon balance in soils and agro-landscapes
- GIS technologies in rational use and protection of soil resources
- Water-saving technologies
- Rational use of forest resources and forest reclamation
- International collaboration on the management of the dry bed of the Aral Sea.

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