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Taking Stock of Human Capital in Soil Science for Central Asia and the South Caucasus

R E P O R T

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Kanysh Nurymgereyev and Thomas L. Thompson

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Images

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About the Authors

Kanysh Nurymgereyev is an Independent Consultant. He holds a Master's degree in Land Use Planning and a PhD in Geography (Natural Resource Management). He has been working for over 20 years in the field of natural resource management for development programs, civil society organizations, and government initiatives in Central Asia and the South Caucasus. He served as a consultant to the World Bank, the Asian Development Bank, the UNDP, and other United Nations agencies. He is the author of more than 20 articles and publications on natural resources management in agriculture.

Thomas L. Thompson is Professor of Agronomy and Soils and Associate Dean and Director of Global Programs in the College of Agriculture and Life Sciences at Virginia Tech. He has been active as a university professor in soil science teaching, research, and extension since completing his graduate degrees in 1991. He has authored more than 60 refereed journal publications. In 2010, he was elected Fellow of the Soil Science Society of America.

Abbreviations

CACAARI	Central Asia and the Caucasus Association of Agricultural Research Institutions
CACILM	Central Asian Countries Initiative for Land Management
CAREC	Central Asia Regional Economic Cooperation
DSSS	Dokuchaev Soil Science Society
EASP	Eurasian Soil Partnership
ECFS	Eurasian Center for Food Security
FAO	Food and Agriculture Organization of the United Nations
FESSS	Federation of Eurasian Soil Science Societies
GDP	gross domestic product
GEF	Global Environment Facility
HEI	higher education institution
HGME	South Kazakhstan Hydrogeology and Melioration Expedition
ICARDA	International Center for Agricultural Research in the Dry Areas
IFAD	International Fund for Agricultural Development
NGO	nongovernmental organization
OECD	Organisation for Economic Co-operation and Development
QA/QC	quality assurance/quality control
TAIC	Training, Advisory and Innovation Centre
TIIAME	Tashkent Institute of Irrigation and Agriculture Mechanization
UNCCD	UN Convention to Combat Desertification
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
USAID	U.S. Agency for International Development

1 Executive Summary

The Eurasian Center for Food Security (ECFS) has brought to the attention of the World Bank the apparently diminishing capacity in soil expertise and stagnant or shrinking job market for soil experts in many regions that suffer from food insecurity. This observation largely reflects the perception of the trend voiced by many African soil science professors and post-graduate students who gathered at the RUFORUM meeting in Cape Town in 2016; it was reiterated at the World Soil Day meetings (2016 and 2017) organized by ECFS with support of the World Bank in Moscow. Such a perception of trends in soil science within the education community raises concern for sustainable development in the agricultural, forestry, and nature conservation sectors around the world.

Soils are a critical resource for maintaining and advancing food security, especially under the pressure of climate change. Soils are the functional support of terrestrial agriculture and ecosystems. Most of the food humanity consumes is produced on land directly utilizing soil reserves of nutrients and water. Large areas of agricultural land are degraded and soils suffer from nutrient depletion, erosion, salinization, and other adverse effects of this utilization.

The constraints on available land resources, particularly in arid parts of the world, impose restrictions on agricultural expansion and require sustainable intensification solutions. Many such solutions to these constraints lie in the domain of soil science and are closely linked to the information and technology soil science can provide.

Soil science informs the optimization of land use and primary production sectors of agribusiness to ensure food security at household, national, regional, and global levels. Human capital is the key component of agricultural advisory services needed to achieve food security through sustainable soil management while balancing the needs of agricultural, industrial, and urban development with the need for the conservation of natural resources and biodiversity.

The countries of Central Asia and the South Caucasus share a common history as former Soviet republics; they also share common challenges related to environmental degradation and food security. Soil degradation, mostly caused by human activities, is a major challenge for the Central Asia and South Caucasus regions. The most serious soil challenges in the region include salinization, erosion, nutrient depletion, and chemical pollution. Other challenges include increasing desertification and drought as well as multiplying environmental threats related to climate change, deforestation, and abandonment of croplands.

There is a strong link between soil and environmental health on the one hand, and food security on the other. Severe food insecurity afflicts about 2 percent of adult Central Asian residents and 5 percent of the adult population of the South Caucasus countries—the highest percentage in the Eurasian region. The prevalence of stunting in children is another key measure of food insecurity.[1] In 2016, more than 10 percent of children in Azerbaijan, the Kyrgyz Republic, Tajikistan, and Turkmenistan suffered from stunting. Improving diets by increasing agricultural productivity in these regions is of paramount importance for improving lives and livelihoods.

Russian soil scientists were pioneers in the discipline, and the countries of Central Asia and the South Caucasus inherited a strong tradition in soil science from the former Soviet Union. However, since independence, the profession of soil science has suffered in both regions from lack of government interest in soil science, which in turn affected investment rates in soil science education and research. Because of low investment, most higher education institutions (HEIs) have not modernized their curricula, teaching methods

[1] Stunting is an anthropometric measure of low height-for-age. It is an indicator of chronic undernutrition and is the result of prolonged food deprivation and/or disease or illness (Shekar et al. 2017).

have not changed in decades, and the research capacity of government-supported institutions has suffered. This study concludes that soil science as a profession is in danger of being viewed as anachronistic at the very time when soils expertise is most needed to help solve serious national and regional food security and environmental challenges.

Within the Central Asia and South Caucasus regions, soil science professionals urgently need to rethink and reposition the discipline to make meaningful contributions to sustainable development and food security in the 21st century. This must include curricular and instructional reform at universities in order to create a "new breed" of soil scientists familiar with cutting-edge knowledge of soils and their management. Modern soil scientists must be equipped with knowledge of international soil science and be familiar with modern soil science tools and concepts, including advanced statistics, spatial science, modern analytical methods, data analytics, digital soil mapping, remote sensing, precision agriculture methods, and systems thinking. Proficiency in English is the exception rather than the rule among soil science professionals in both regions. Because English is the international language of science, soil science professionals should gain English proficiency in order to participate in international soil science exchanges and practice.

Soil science education programs in countries of Central Asia and the South Caucasus must be benchmarked against international standards. Soil scientists must emphasize the many applications of soil science to make vital contributions to food security, land use planning and management, natural resources conservation, and ecosystem services. To promote job opportunities, soil science must also be strongly linked to private sector needs for agribusiness, agricultural extension, and land management. Soil science research programs must be revitalized and focus on solving specific problems of the regions. University management must support this recommended modernization of soil science curricula, education, and research. Governments must do their part as well, by providing resources to empower this vital discipline to contribute productively to sustainable development.

2 Introduction

The Central Asian countries include Kazakhstan, the Kyrgyz Republic, Tajikistan, Turkmenistan, and Uzbekistan. The South Caucasus countries are Armenia, Azerbaijan, and Georgia. These countries lie in arid to sub-humid zones, and land use is dominated by irrigated crop production and animal agriculture based upon grazing. The countries share a common history as former Soviet republics and common challenges related to environmental degradation and food security. Soil degradation is a major challenge for the regions. For example, soil salinization is a serious problem in Kazakhstan, Turkmenistan, and Uzbekistan (Krasilnikov et al. 2015). In much of the region, soil erosion and nutrient depletion threaten food production. Other serious problems in the region include increasing desertification and increasing environmental threats related to climate change (Beniwal et al. 2010), deforestation, and abandonment of croplands. Mirzabaev et al. (2015) reported that the annual costs of soil degradation in Central Asia were US$6 billion between 2000 and 2009.

Table 1 summarizes some key population and food security indicators for the regions. Food security in Central Asia and the South Caucasus has been negatively impacted by environmental and economic factors. Severe food insecurity afflicts 2.1 percent of adult Central Asian residents and 5.4 percent of the adult population of the South Caucasus countries, the highest percentage in Europe and Central Asia (FAO 2017). In 2016, the prevalence of stunting among children under five years old was greater than 10 percent in Azerbaijan, the Kyrgyz Republic, and Turkmenistan, and was 27 percent in Tajikistan (FAO 2017).[2] Although the food security situation has improved recently, challenges remain because of progressive land degradation.

Soil is the basis for all terrestrial ecosystems, and adequate soil resources are essential for productive and profitable agriculture. The soils of Central Asia and the South Caucasus are under threat from human abuse and climate change. Critical soil needs for the present and future include halting and reversing the spread of soil salinization, stopping the erosion of sloping lands due to overgrazing, restoring soil fertility, and improving soil management to

Table 1. **Key Population and Food Security Indicators for Central Asian and South Caucasus Countries**

Country	Population (millions)*	Population growth rate (%)*	GDP per capita (U.S. dollars)†	Arable land (%)*	Population living on degraded land (%)†	Child stunting (%)†	Prevalence of undernourishment (%)†
Armenia	3.05	−0.21	3,800	16	10	9.0	4.4
Azerbaijan	9.96	0.87	6,100	23	4.0	18	<2.5
Georgia	4.93	−0.02	4,000	5.8	2.0	11 ‡	7.0
Kazakhstan	18.6	1.0	10,600	8.9	24	8.0	<2.5
Kyrgyz Republic	5.79	1.0	1,000	6.7	10	12	6.4
Tajikistan	8.47	1.6	930	6.1	11	27	30
Turkmenistan	5.35	1.1	6,900	4.1	11	12	5.5
Uzbekistan	29.7	0.93	1,900	10	27	19 ‡	6.3

* Data from CIA, 2018.
† Data from FAO, 2017. Data shown are 2015 GDP in constant 2010 U.S. dollars.
‡ Data from UNDP, 2013b.

[2] Stunting is an anthropometric measure of low height-for-age. It is an indicator of chronic undernutrition and is the result of prolonged food deprivation and/or disease or illness (Shekar et al. 2017).

restore soil health (Beniwal et al. 2010). Three key ingredients are needed to accomplish these daunting tasks. First, the resolve to halt soil degradation and restore degraded soils. Second, the resources needed to implement appropriate technical and management solutions for soil degradation. Third, human capital in soil science that is critical for achieving these goals.

The objective of this project is to assess the status of human capital in soil science within Central Asia and the South Caucasus. Russians were some of the pioneering soil scientists in the late 19th and early 20th century. Within the Soviet Union, soil science was prominent among the agricultural disciplines. However, since the breakup of the Soviet Union and independence in 1992, soil science in the former Soviet republics has suffered, along with many other agricultural disciplines. According to Beniwal et al. (2010, p. 14):

> All the eight countries in the . . . region inherited from the former Soviet Union high quality agricultural research and education systems with strong linkages with one another and wealth of research experience from the Soviet era. This provided them fairly good foundation to build-on collaborative agricultural research for development. However, during post-independence, the . . . systems in each country have suffered due to insufficient support provided to them by the countries in the region. Similarly, the strong linkages that these institutions had with one another have been broken. Thus, the inherited wealth of research experience by these countries from the former Soviet Union, which provided a fairly good foundation to build-on collaborative agricultural research, has been disrupted.

We set out to evaluate whether the human capital in soil science within Central Asian and South Caucasus countries is sufficient to meet the food security and environmental challenges facing them now and is likely to remain so in the near future. Our evaluation was built around visits to each country in the regions (except Turkmenistan) to pose questions to key participants and stakeholders within the soil science profession and end users of soil information in the public and private sectors. We acknowledge some ambiguity regarding the definition of a *soil scientist*. We did not limit our investigation to degreed soil scientists only—indeed, we found it impossible to limit our investigation in this way. We also considered other professionals, such as agronomists and horticulturalists with significant soil science expertise. Our questions regarding what constitutes "soil science" or "soil scientists" were open to some interpretation by those we interviewed. However, we believe this is appropriate given the applied nature of much soil science, and the fact that soil science itself can be applicable to many fields of endeavor, most notably agriculture, land management, and environmental science.

It is important also to distinguish between "fundamental" and "applied" soil science. We define *fundamental soil science* as the study of the origin of soils; their classification within recognized classification systems; and the understanding and quantifying of important physical, chemical, and biological properties of soils. *Applied soil science* is the application of a fundamental understanding of soils to address challenges in environmental protection, land use planning, land and habitat restoration, and food production. Courses in soil science may also be found within curricula in ecology, environmental science, agronomy, and forestry. Individuals who matriculate through such programs will possess soil expertise, but they are generally not considered to be "soil scientists."

Applied soil science is soil expertise applied to real-world problems. Because of current and expected soil degradation within the regions, there continues to be a huge need for applied soil science expertise within Central Asia and the South Caucasus. In general, we found that the necessary human capital does exist now, but we are not optimistic about the future of applied soil science within the regions. However, applied soil science will eventually disappear unless it has a strong basis in fundamental soil science, especially at universities. In most countries of the region, HEIs are in need of reform and additional resources (Beniwal et

al. 2010). Young people currently are neither attracted to academic careers, nor to careers in agricultural sciences in general. The current situation for soil science within the regions is deeply concerning, and improving the situation should be a priority for leaders within government and academia.

3 Soil Science in the Face of Challenges to Agricultural Development and Environmental Protection in Central Asia and the South Caucasus

Today the production of food is one of the greatest challenges facing humanity, and it demands multidisciplinary study of environmental issues, limits to agricultural production (because of the degradation of soil), and answers to social questions of food security (Marsden and Morley 2014).

Consequently, the supply of food in the face of the growing population and increasing soil degradation means that there is an urgent need to improve soil science education, research, and extension to provide farmers with information about sustainable and effective agro-technology and approaches. Improved knowledge and management of soils are also key to tackling environmental challenges, restoring degraded lands, and protecting vulnerable lands from further degradation.

Central Asia and the South Caucasus are mostly arid to semi-arid. This, plus decades of land mismanagement, have resulted in some of the world's most seriously degraded soils. A recent Food and Agriculture Organization (FAO) document (Krasilnikov et al. 2015) summarizes the status of soils in the regions and associated human health challenges. Up to 43 percent of all agricultural land in the South Caucasus is eroded. Much of this erosion has been caused by poor grazing management and is exacerbated by the sloping nature of the terrain. About 100 million hectares in Central Asia have been degraded by water and wind erosion. Poor irrigation management has resulted in extensive secondary soil salinization in Central Asia, especially in Kazakhstan and Uzbekistan. A total of 41 percent of Kazakhstan and 46 percent of Uzbekistan have been degraded by secondary salinization; 24 percent and 27 percent, respectively, of the population lives on degraded land. Eighty percent of all agricultural land in Uzbekistan is eroded.

Soil degradation is among the many factors contributing to food insecurity in the regions. Prevalence of undernourishment in Central Asia decreased during 2005–16;[3] however, more than 8 percent of the population remains undernourished. A similar decline was observed in the South Caucasus, with 3 percent of the population undernourished in 2016 (FAO 2017). Undernourishment is a more severe problem for the young. In 2016, more than 25 percent of children in Tajikistan under five years of age were stunted. Within the South Caucasus, stunting of children was highest in Azerbaijan, at 17 percent (FAO 2017).

3.1 Soil Health in Central Asia and the South Caucasus: The Main Challenges

Central Asia and the South Caucasus are suffering from serious environmental problems, including soil degradation. Salinization of agricultural soils in these regions poses a grave threat to agriculture and influences rural livelihoods, which have become progressively more dependent on the income from degraded soils. The major drivers of soil degradation in Central Asia and the South Caucasus include unsustainable agricultural practices, the expansion of crop production to marginal areas, inadequate maintenance of irrigation and drainage networks, and overgrazing near settlements. Fragmentation of agricultural land because of the dissolution of former collective farms has resulted in thousands of very small agricultural parcels that are not managed efficiently.

Ineffective soil management in Central Asia and the South Caucasus is closely related to low rates of investment in preventing soil degradation and reclaiming degraded land. This low rate of investment is the

[3] The prevalence of undernourishment is an estimate of the proportion of the population whose habitual food consumption is insufficient to provide the dietary energy levels that are required to maintain a normal active and healthy life. It is expressed as a percentage. See SDG Indicator 2.1.1 - Prevalence of undernourishment, available at http://www.fao.org/sustainable-development-goals/indicators/211/en/.

result, primarily, of the smallholder land tenure model and the limited capacity of national institutions to provide extension services and upscale sustainable approaches and technologies in agriculture. In most cases, known approaches that are difficult and costly to implement require new forms of agricultural knowledge and expertise.

Although soil degradation is widespread in the two regions, degradation is most severe in the north and east of Kazakhstan to the southern part of Central Asia, covering the Kyrgyz Republic, the northwest of Tajikistan, and the southern parts of Uzbekistan and Turkmenistan. According to the UNEP, inappropriate land use practices led to decreases of the area of agricultural lands in Kazakhstan from 221 to 78 million hectares during 1990–2004 (UNEP 2007). The main causes of the reduction of agricultural area were (1) secondary salinization in irrigated lands; (2) soil erosion in rainfed and mountainous areas; and (3) loss of vegetation, desertification, or detrimental change in the vegetation composition of rangelands.

Wind and water erosion, often influenced by anthropogenic activities, has occurred in the Kyrgyz Republic and led to the destruction of a significant part of the topsoil. As a result, more than 40 percent of agricultural land is degraded and more than 85 percent of land is exposed to processes of desertification and soil degradation (UNDP-UNEP, no date).

Considerable areas of soil in Tajikistan are also subject to degradation. Large areas of the country's agricultural land are affected by erosion and salinization, while the quality of 97 percent of the arable land has severely declined in the past 15 years (Mustaeva et al. 2015). The worsening technical status of irrigation systems resulted in the irrigation erosion of 1 percent of the area of the country. About 12–15 percent of irrigated lands are subject to permanent waterlogging because of a shortage of adequate drainage systems.

Secondary salinization and waterlogging of soils also predominate in Turkmenistan and are widespread in irrigated regions. Almost 95 percent of the total irrigated area of Turkmenistan has been exposed to salinization to varying degrees. One of the main factors driving the salinization and contamination of irrigated soils in the country is the use of highly mineralized water from the Amu Darya River for irrigation (Berdiyev 2006).

The extensive cotton monoculture system long practiced in Uzbekistan has exhausted the soil, reduced soil fertility, harmed the physical structure of soils, and intensified erosion. About 50 percent of the agricultural land area of the country is subject to soil erosion and degradation. Altogether, in Uzbekistan more than 50 percent of irrigated lands are salinized (FAO 2012).

According to the National Action Plan to Combat Desertification in Armenia, about 24,353 square kilometers—or 82 percent of total land area (excluding the surfaces of Lake Sevan and water reservoirs)—are to different extents exposed to desertification: 26.8 percent of the total territory of Armenia faces extremely severe desertification; 26.4 percent, severe desertification; 19.8 percent, moderate desertification; and 8.8 percent, slight desertification. Only 13.5 percent (400 square kilometers) of the territory is not exposed to desertification (Suvaryan and Sargsyan 2008).

3.2 Soil Health and Food Security: Central Asia and the South Caucasus

The countries of Central Asia and the South Caucasus were important for agricultural production within the former Soviet Union, and they still have high potential for food production. However, as result of political and social changes and land degradation, food insecurity is now a serious problem in the regions.

In all countries of Central Asia and the South Caucasus—including the countries with oil- and gas-oriented economies—agriculture plays an essential role as an employer, especially in rural areas, and is an important contributor to gross domestic product (GDP). Moreover, agriculture remains one of the main pillars of social stability and food security in these countries, because about 44 percent of the population in the Caucasus countries and about 60 percent in Central Asia live in rural areas. Soil conditions that

heighten the risk of land degradation in the whole Central Asian region include salinity, sodicity (degree of sodium accumulation in soil), waterlogging, soil shallowness, and risk of erosion (FAO 2000).

Approximately 600,000 hectares of irrigated cropland in Central Asia has become derelict over the past decade as a result of waterlogging and salinization. It is estimated that in Uzbekistan alone approximately 20,000 hectares of irrigated land is lost to salinity and abandoned each year (Bucknall et al. 2003). The accumulation and migration of salts to the soil surface causes degeneration of the vegetation community and decreased botanical diversity of rangelands. This, in turn, affects the productivity of the livestock system and the livelihoods of the people. According to some studies, fodder production has declined by 9–14 percent because of soil degradation, including loss of soil fertility and secondary salinization (Lamers and Khamzina 2010).

Soil degradation leads to decreasing income of rural populations in agricultural areas that not only causes rural poverty but also increases the risks of interstate conflicts over land and water. Some regions, such as the Fergana valley in Central Asia, still have high conflict potential fueled by land scarcity. Therefore, the national and regional strategies for food security and social stability in Central Asia and the South Caucasus need to be focused on soil health.

4 Soil Science in Central Asia and the South Caucasus

Improving the state of soil science in Central Asia and the South Caucasus will underpin the needed growth in the number and capabilities of soil scientists who will be able to tackle the challenges ahead. This will require improving capabilities of soil science in education, research, and extension.

4.1 The State of Soil Science Education

Higher education institutions (HEIs) in general and soil science education in particular are still heavily influenced by the legacy of the Soviet education system. Key features of this system include a lack of autonomy by HEIs, control of academic programs by government ministries, and faculty-centric instructional methods. Teaching methods have changed little in decades, and include an emphasis on rote memorization and recall, and only limited experiential learning. A 2014 World Bank document on higher education in Uzbekistan (World Bank 2014) noted several challenges that exist to significant degrees in the HEIs of most countries of these regions. These include the oversight of universities by government ministries, which limits institutional autonomy to reform academic programs of study. Low salaries for academic staff are endemic throughout the region (cf. ADB 2015; OECD/World Bank 2007), and government spending on higher education is generally low. Research in soil science at universities is limited, usually poorly connected with extension, and not informed by private sector needs (Beniwal et al. 2010).

Reforms have been undertaken in most countries, and development agencies such as the World Bank and the Asian Development Bank have initiated programs to strengthen higher education within the regions. In most cases, it is too soon to know whether systemic reform will occur. For example, the Government of Uzbekistan will now allow universities to develop their own curricula, and the country is in the process of joining the Bologna process (World Bank Tashkent office, August 27, 2018, personal communication). Nevertheless, higher education across the region remains weak and needing reform.

The situation in higher education in agriculture is perhaps more serious than it is for higher education in general. Private universities have been established in several countries of the regions, including Armenia, Azerbaijan, Georgia, Kazakhstan, and the Kyrgyz Republic. Private universities may have more autonomy than public universities, often use modern pedagogical methods to a greater degree, and may be better funded. In general, however, private universities do not offer academic programs in agricultural disciplines, including soil science. Thus the advantages of private universities have not influenced agricultural curricula and pedagogy. Uniquely, the Agricultural University of Georgia, located in Tbilisi, was privatized several years ago.

Soil science as a discipline has traditionally been associated with agriculture. Russian soil scientists were pioneers in the study of soil formation and soil classification. Thus soil science was an area of strength within Soviet universities that included agricultural disciplines. Since independence, soil science has arguably fared less well than in former times. Faculties or departments of soil science continue to exist at many universities offering agricultural disciplines (Table 2), but enrollments have dropped and most curricula have not been substantially revised since independence. It seems that within HEIs, soil science is increasingly seen less as a distinct discipline than as a subject that contributes to agronomy, land management, ecology, and other disciplines. Notably, there is no Armenian HEI with a soil science department or that offers an undergraduate degree in soil science.

It is important to distinguish between "fundamental" and "applied" soil science. We define *fundamental soil science* as the study of the origin of soils; their classification within recognized classification systems; and the understanding and quantifying of important physical, chemical, and biological properties of soils. *Applied soil science* is the application of a fundamental understanding of soils to address challenges in environmental protection, land use planning, land

Table 2. **Major Public Universities Featuring Expertise in Soil Science**

Country	Major institutions for agricultural disciplines	Faculty or department of soil science?	Offers Bachelor's degree in soil science?
Armenia	Armenian National Agrarian University	No	No
Azerbaijan	Baku State University	Yes	Yes
	Azerbaijan State Agricultural University	Yes	Yes
	Ganja State University	Unknown	Unknown
Georgia	Agricultural University of Georgia	Yes	Unknown
Kazakhstan	S. Seifullin Kazakh Agrotechnical University	Yes	Yes
	Kazakh National Agrarian University	Yes	Yes
Kyrgyz Republic	Kyrgyz National Agrarian University	Unknown	Unknown
Tajikistan	Tajik Agrarian University Named after Shirinsho Shotemur	Yes	No
Turkmenistan	Turkmen Agricultural University Named after S. A. Niyazov	No	Unknown
Uzbekistan	Tashkent State Agrarian University	Yes	Yes
	National University of Uzbekistan	Yes	Yes

and habitat restoration, and food production. Courses in soil science may also be found within curricula in ecology, environmental science, agronomy, and forestry. Individuals who matriculate through such programs will possess soil knowledge, but they are generally not considered to be "soil scientists." Soil knowledge is key to solving agricultural and environmental problems. However, over the long term, soil knowledge will not exist without a strong basis of human capital in soil science education, research, and extension.

During the two missions, team members for this study were able to visit the leading HEIs in the region offering agricultural programs and interact with key personnel at the faculty, department, and administrative levels. The lone exception was in Georgia.

We also attempted to connect with national soil science societies, if they existed. Results were mixed. The team learned that the Uzbekistan Soil Science Society has about 250 members, but "activities were stopped" because of the actions of an unspecified government ministry. The president of the Azerbaijan Soil Science Society claimed a membership of 600, but also professed dissatisfaction with the low level of activity of the society. We learned from multiple individuals that the Armenian Soil Science Society has only 15 members. The lack of strong and active national professional societies will further weaken the profession.

4.2 The State of Soil Science Research

HEIs within the regions conduct research. However, in Soviet times most soil science research was conducted within institutes affiliated with government ministries or national academies. In each country, these institutes still exist, although they may now be affiliated with different government entities (Table 3). In Armenia, the Scientific Center for Soil Science, formerly a government institute, is now affiliated with the Armenian National Agrarian University. In most countries, however, the former Soviet structure persists, and the institutes are still under management of a government ministry.

In general, the institutes and centers with responsibility for soil science research have had responsibility for soil mapping and delineating suitable land uses. In some cases, these responsibilities

Table 3. **Major Public Institutions, Other than Universities, Conducting Soil Science Research, and Their Governing Bodies**

Country	Institutions	Governing Body
Armenia	Scientific Center for Soil Science	Armenian National Agrarian University
Azerbaijan	Soil Science and Agrochemistry Institute	National Academy of Science
Georgia	Scientific Research Center of Agriculture, Soil Fertility Research Service	Ministry of Environmental Protection and Agriculture
Kazakhstan	Kazakh scientific Research Institute of Soil Science and Agrochemistry Named after U. U. Uspanov	National Agricultural Research and Education Center, Ministry of Agriculture of Kazakhstan
Kyrgyz Republic	Kyrgyz Agricultural Research Institute	Ministry of Agriculture, Food Industry and Melioration of the Kyrgyz Republic
Tajikistan	Tajik Soil Science Research Institute	Tajik Academy of Agricultural Sciences
Turkmenistan	National Institute of Deserts, Flora and Fauna of the Ministry of Nature Protection of Turkmenistan	Ministry of Nature Protection of Turkmenistan
Uzbekistan	Institute of Soil Science and Agrochemistry	Ministry of Agriculture
	UZGIP Scientific Research and Design and Surveying Institute	Ministry of Water Resources
	Scientific Production Center for Agriculture	National Academy of Sciences

continue. For example, the Institute of Soil Science and Agrochemistry in Uzbekistan continues to map soils and provide land capability and soil fertility recommendations. UZGIP in Uzbekistan still develops soil maps for irrigation suitability. The Soil Science and Agrochemistry Institute in Azerbaijan employs more than 70 Candidates of Science or equivalent. However, as we learned, analytical methods date from Soviet times and new methods of analysis are not possible due to a lack of equipment. In contrast, the Scientific Research Center of Agriculture, Soil Fertility Research Service near Tbilisi, Georgia is well equipped with modern analytical equipment for soil science research. This center seems to be conducting research that is relevant to current issues in Georgia. The Scientific Center for Soil Science in Yerevan, Armenia employs 37 staff with PhDs or equivalent.

We estimated relative research output with a Web of Science literature search. For each of the Central Asia and the South Caucasus countries, we searched for papers published in refereed journal publications in English within the past five years that included the search term "soil" and the country name. We reviewed the paper titles and eliminated those that were not within the realm of soil science (as defined above). Results are reported in Table 4. It was not possible to evaluate which papers originated from in-country research organs, but these data do provide a relative measure of published research output. The relatively high number of publications related to Kazakhstan and Uzbekistan are consistent with our other findings. The results from Georgia may not be accurate, as it was difficult to distinguish

Table 4. **Refereed Journal Publications Indexed by the Web of Science**

Country	Number of Publications
Armenia	16
Azerbaijan	22
Georgia	14
Kazakhstan	50
Kyrgyz Republic	10
Tajikistan	10
Turkmenistan	2
Uzbekistan	43

Note: The data show refereed journal publications related to soil science published in English within the last five years.

between results from the Republic of Georgia and the U.S. state of Georgia. These results suggest that about 32 journal articles about soils are published each year in English, across the regions. It was not possible to evaluate the numbers of articles published in other languages.

Throughout the two regions, agricultural research has suffered since independence for several reasons. Research connections among the countries that were maintained in the former Soviet Union have been disrupted. In general, most countries have invested little in agricultural research since independence. Low salaries make it difficult to attract young talent to agricultural research. Finally, agricultural research, education, and extension have not been well coordinated (Beniwal et al. 2010). Our observations during our missions confirm that this situation still exists within soil science research institutions in Central Asia and the South Caucasus.

4.3 The State of Soil Science Extension

This section looks at the strengths and weaknesses in soil science extension in each of the Central Asia and South Caucasus countries.

Central Asian Countries

Kazakhstan

The promotion of agricultural innovations and the development of educational information and consulting activities in Kazakhstan are the responsibility of the Ministry of Agriculture. Joint stock companies established under the Ministry of Agriculture carry out the projects that focus on improving the skills and knowledge of rural producers through the transfer of new knowledge and technologies and applied research, as well as through practical application in the fields. The distribution of the systems of knowledge in the agro-industrial complex covers a wide range of areas in education and training, and includes consulting activities organized for local farmers in rural areas through the involvement of specialists in different fields of the agricultural sector. The government tries to create a good platform for the development of the agricultural sector with the help of scientific innovations. Since 2009 until the present, six centers operate in the country with the primary important task of meeting the needs of rural producers and the objective of developing agricultural industries in various regions of the country (Andirova 2014). The most positive factor in Kazakhstan's soil science outlook is that the government remains committed to providing effective extension services to its farmers.

The Kyrgyz Republic

An ambitious process of agricultural reforms in the Kyrgyz Republic began in 1998. In accordance with the provisions of land reform, the former *sovkhozes* (state farms) and *kolkhozes* (collective farms) were dissolved and agricultural lands were distributed among land users and farmers. In order to fulfil extension and training needs of individual farmers in the Kyrgyz Republic, a few large projects, supported by international organizations, were realized between 1995 and 2010. These projects were focused on establishing rural advisory service centers and advisory training centers, developing a new form of training for farmers, and boosting the capacity building of the Ministry of Agriculture and the Water Resources and Processing Industry. Although a number of non-public extension advisory bodies have been created, their inputs remain weak. Eventually, some of the centers established with international donor support have been transformed into private centers, such as the Training, Advisory and Innovation Centre (TAIC) and Rural Advisory Services, Chui Talas.

Tajikistan

The agricultural extension system in Tajikistan is rather insignificant; collectively it impacts less than 10 percent of the country's farm households. It is mostly presented by two main players, which have been using different approaches: there is a state

system with a strong administrative organizational structure but with weakened capacities, on the one hand, and numerous good skilled and active non-governmental organizations (NGOs) supported by donor-specific projects, but with a lack of sustainability and weak communication between each other, on the other. Many overlapping duties and duplications exist not only between the state organizations and NGOs but between different NGOs as well. At the same time, most small farmers operate within small and medium-scale *dehkan* farms (individual or family farms in some countries of Central Asia) and have very limited knowledge about farm management. The biggest concern is that an institutional extension system in Tajikistan still not established.

Turkmenistan

Limited agricultural extension services in the country are offered via district administrations and agricultural cooperatives and farmers' organizations, which are insufficient in promoting best practices in efficient and sustainable soil management. Worse still, district and collective extension services are located at a considerable distance from farmers, who have no access to the Internet or to open information sources. There have been a few efforts to improve extension services in partnership with international development organizations, including a European Union–supported project such as AgroNet, but these have proven unsustainable and are no longer operational. The state commercial agricultural bank Daikhanbank has its own agricultural experts in all local branches; however, their mandate is limited to only controlling the timing and area of crop planting. Because of the cumbersome system of governance, available state financial support for the agricultural sector is ineffective in delivering resources to smallholder farmers and unable to ensure access to resilient technologies. Smallholder farmers generally lack the financial capacity to procure equipment, which is needed for sustainable soil management and maximal agricultural output. Agricultural cooperatives and farmers' organizations, in their turn, do not invest in efficient agricultural technologies because they lack of incentives and skills for efficient soil use.

Uzbekistan

In line with reforms conducted in the agriculture sector of Uzbekistan since 1992, various forms of extension and advisory services—such as farmer-to-farmer initiatives and demand-driven models—have emerged. During the past several years, the Ministry of Agriculture (formerly the Ministry of Agriculture and Water Resources) on behalf of the government has been responsible for the coordination of all agricultural activities, including extension services to the farmers in the country.

South Caucasus Countries

Armenia

Armenia initiated the establishment of agricultural extension and advisory services in 1991, when collective and state farms (kolkhozes and sovkhozes) were gradually dismantled and the land was distributed among individuals. The new farm owners needed technical advice and information support to operate their farms profitably, and only formal extension service could help them to get it. USAID, the World Bank, and other donor and development agencies provided financial and technical assistance to Armenia in the development of an agricultural extension system.

The foundation of an extension system was developed through the following donor-funded projects, including:

- The Farmer-to-Farmer Program initiated in Armenia in 1992
- The Armenian/American Extension Project implemented from 1993 to 1995
- The Agricultural Extension Department established within the Armenian National Agrarian University
- The Agricultural Training Center, established as an academic department within the Armenian Agricultural Academy

For the time being, the public extension system in Armenia is composed of three national-level players: the Agricultural Support Republic Center of the Ministry of Agriculture, the Armenian National Agrarian University, and national agricultural research centers; it also includes a network of regional agricultural support centers.

Azerbaijan

Public entities in rural areas are institutionally weak and lack the capacity for managing, implementing, and monitoring external services. Their role is restricted, most often, to promoting and administering state policy at the local level and collecting statistical information for the respective ministries. At the same time, the donor community in Azerbaijan, led by the World Bank, made great strides to establish a functioning network capable of providing farmers with extension services and the technical information they need. As a result, the whole country is currently served by these extension service centers. The services are mostly provided through the regional extension service centers and village-based advisors with certain knowledge in soil science, such as agronomy or agrochemistry, and who are generally well known in their areas. However, the biggest concern with this approach is whether or not it will be sustainable without donors' support. There are also local NGOs, community-based organizations, and consulting centers playing the role of implementing agencies to provide advisory and extension services in the agricultural sector for the rural population. The civil society in Azerbaijan is quite active in agricultural and rural development, but it is mainly dependent on donor support. The private sector, which provides only fee-based services such as soil analysis, is very weak, underdeveloped, and unable to compete with the state system and donor community.

Georgia

One of the biggest issues with regard to agriculture and land use in Georgia is accessible information about soil conditions, new agro-technologies, and what approaches to use. The provision of advisory and extension services, like much of the agricultural sector, had been subjected to wide-scale privatization; by now, the state's role in providing such services is significantly reduced. Given the limited amount of money that is available through government channels to support farmers, one of the key providers of extension and advisory services over the years in Georgia has been international organizations and development institutions. Projects and programs—mostly financed by the World Bank, the Swiss Development Corporation, Mercy Corps, and USAID—are run by United Nations agencies and focus considerable attention on the development of agricultural service centers that offer access to extension services and agricultural advice.

4.4 The State of Soil Science Societies and Regional Cooperation

Soil science societies in Central Asia and the South Caucasus were established in the early 2000s and operate as public associations at national soil research institutes or national agrarian universities. They have been collaborating with the international soil organizations, such as the Eurasian Soil Partnership, the Eurasian Center for Food Security (ECFS), and the Dokuchaev Soil Science Society (DSSS).

The DSSS is a public organization that coordinates soil research for the preservation and management of soil resources. Its main activity is to organize conferences and workshops on soil science and promote soil health and conservation. Within Central Asia and the South Caucasus, the DSSS has two subdivisions, one in Azerbaijan and one in Uzbekistan. The Eurasian Soil Partnership (EASP) comprises 13 countries, including the countries of Central Asia and the South Caucasus, and aims at implementing sustainable soil management practices in the Eurasian subregion. Some soil science societies work under the Federation of Eurasian Soil Science Societies (FESSS), which was established in 2012 by the collaboration of the soil science societies of four countries: Turkey, the Russian Federation, Azerbaijan, and Kazakhstan. After 2016, the Kyrgyzstan Soil Science Society joined FESSS.

Kazakhstan

A professional society of soil scientists, agroecologists, and agrochemists was established in 2008 and based at the Kazakh Research Institute of Soil Science and Agrichemistry, named after U. U. Uspanov. In October 2018, the society hosted an International Soil Science Congress on Environment and Soil Resources Conservation in Kazakhstan.

The Kyrgyz Republic

The Kyrgyzstan Soil Science Society is named after A. M. Mamytov. The society has over 50 members, including 20 active members. The Kyrgyzstan Soil Science Society is a member of the Eurasian Soil Partnership, the Global Soil Partnership, and the FESSS. In 2016, members of the society, jointly with soil scientists from Mongolia, initiated the establishment of the Soil Science Society of Central Asia. In partnership with soil scientists from Humboldt University (Berlin, Germany), this society is implementing a project for monitoring soils in the Kyrgyz Republic.

Insufficient information has been found in open sources on the activity of soil science societies in the other countries of Central Asia and the South Caucasus. According to existing information, the main activity of the societies is boosting the participation of its members in international conferences and forums. Based upon personal interviews during site visits, we concluded that most country-based soil science societies are currently not very active. For example, we were told that the Uzbek Soil Science Society has more than 250 members, but "activities have stopped" because of unidentified government intervention. The President of the Azerbaijan Soil Science Society claimed 600 members, but professed disappointment with the low level of activity of the society. We heard that the Georgian Soil Science Society has 40–50 members, but several young scientists told us that they are not members. The Armenian Soil Science Society has only 15–20 members. A review of literature on soil science societies did not find any information on the existence of such a society in Turkmenistan.

The EASP is a part of the Global Soil Partnership. All eight countries under consideration are included in EASP, the goal of which is ". . . the implementation of sustainable soil management practices at a wider scale, especially in areas affected by soil salinity."[4] A representative of the Kyrgyzstan Institute of Land Management is included in the EASP Steering Committee. The Eurasian Soil Portal (http://eurasian-soil-portal.info/index.php/en/) is part of the EASP Implementation Plan, but is not yet active.

The CACILM multi-country project (Central Asian Countries Initiative for Land Management) was funded by the Global Environment Facility (GEF), the International Fund for Agricultural Development (IFAD), the Asian Development Bank, and many others. The objective of CACILM was to ". . . to increase capacity at the national and cross-country levels to develop and implement an integrated approach and strategies to combat land degradation" (UNDP 2013a). CACILM (2007–13) included partners from each Central Asian country, including several organizations consulted for the preparation of this report. Research institutes and government ministries are included as CACILM partners. However, no universities are included on the list of project partners found at http://www.cacilm.org/en/about/project/partners. The final report about CACILM (Hurst et al. 2013) does not provide information regarding achievements related to capacity building outcomes in soil science. CACILM-II (2013–16), funded by IFAD and implemented by the International Center for Agricultural Research in the Dry Areas (ICARDA), aimed to create a knowledge platform to support sustainable land management in Central Asia. Target groups included extension agencies and NGOs, but not universities or research institutes.

[4] See http://www.fao.org/global-soil-partnership/regional-partnerships/europe/eurasia/en/ for details about the EASP.

5 Methodology

Within the framework of the study, a large number of meetings were held with individuals and groups of experts at universities, research institutes, government ministries, extension services, and private sector organizations in Central Asia and the South Caucasus. We used a combination of in-person interviews, online interviews, and an e-survey to ascertain respondents' opinions regarding the status of human capital in soil sciences.

During June 2018, Kanysh Nurymgereyev carried out a mission to the capitals of Kazakhstan, the Kyrgyz Republic, and Tajikistan, spending three to five days at each location. During July 2018, Nurymgereyev and Thomas Thompson carried out a mission to the capitals of Uzbekistan, Azerbaijan, Georgia, and Armenia, spending three to five days at each location. The purpose of the missions was to visit (on-site or at a neutral location) as many key institutions connected with soil science as possible. We conducted follow-up conference calls with two World Bank country offices. Two other World Bank offices did not respond to such requests. A list of individuals and institutions visited during the two missions is given in Annex 2.

Each visit was one or more hours long and attended by one to several individuals. The meeting formats were similar. After introducing ourselves and describing our mission, typical questions asked of the interviewees included:

- Please describe the mission, activities, and governance of your organization.
- What are the most serious soil-related issues in the country?
- What are the most important organizations in the country addressing education, research, and extension in soil science?
- As a discipline, is soil science healthy in the country? (Interviewees were asked to elaborate on their answers.)
- Are there enough soil scientists with the right skills to meet the future needs of the country?
- Are there good employment opportunities for soil scientists?
- Where do soil scientists find employment?
- Are local universities successfully educating future soil scientists?

We asked university departments detailed questions about curricula, quality assurance/quality control (QA/QC) for teaching and curricula, governance, and size and demographics of the student body. For the most part, we were able to meet with relevant university administrators at the dean and/or department head level, and in some cases with faculty. Thus we were able to interview those with responsibility for academic program and teaching quality. The lone exception was the Agricultural University of Georgia, where we met only one professor.

An electronic survey was sent to key individuals in the countries of Central Asia and the South Caucasus in August 2018 to clarify the state of soil science in regard to education and research. Surveys were sent to 30 individuals; 12 responded, a response rate of 30 percent.

The tool used was an individual questionnaire. Because of the limited sample size, we rated the value of the e-survey below that of the on-site interviews.

Respondents indicated the following:

1. Approximately 70 percent of the respondents have more than 20 years of experience.
2. 100 percent of respondents have a higher education degree.
3. Approximately 70 percent of respondents have a PhD in Agriculture.
4. More than 70 percent considered the state of soil science in their respective countries to be

satisfactory and only 14 percent considered it to be negative.

5. About 30 percent agreed that, overall, the professional capacity of soil scientists is low.

6. Soil science professionals have an equal presence in agricultural enterprises (farms and cooperatives) and regional and district departments of the Ministry of Agriculture of the respective countries (28 percent for each).

6 Results and Discussion

Considering the number of countries, institutions, and individuals included in our interviews, the degree of agreement was significant. A coherent picture of the status of human capital in soil science emerged from these visits. Our missions yielded the following key findings, which will inform our recommendations regarding higher education in soil science:

6.1 Human Capital in Soil Science

- There is general agreement that there are well-qualified fundamental soil scientists throughout the region. This is in part a holdover from Soviet times. As a group, these fundamental soil scientists tend to be late in their careers. There are not similar numbers of younger soil scientists "waiting in the wings."
- Opinions varied as to whether human capital in soil science is adequate to meet current and future challenges. However, the most common answer was "no."
- Across the regions, it is difficult to attract young people to soil science.
- Low salaries and lack of other career incentives are disincentives to study and find employment in soil science across the regions.
- Perceptions of the health of soil science vary significantly. For the most part, individuals from private or international organizations ranked the sufficiency of human capital in soil science much lower than did individuals within universities or government agencies.

6.2 Education in Soil Science

- Soil science education throughout both regions emphasizes theory at the expense of practice.
- With few exceptions, academic benchmarking of soil science programs is not performed to international standards. Most academic program QA/QC remains under the authority of government ministries, a situation that has remained unchanged since independence.
- The lack of English proficiency among academic staff at HEIs is of concern. English is the international language of science, and staff who do not read or write in English risk becoming "scientifically isolated." The gradual loss of proficiency in Russian language among academic staff exacerbates this problem. Previously, proficiency in Russian provided a link among soil scientists in former Soviet Union Republics.
- Since independence, all the HEIs of the countries in Central Asia and the South Caucasus had transitioned to use of national languages. As a result, universities experience a lack of textbooks and training manuals. In some countries, such as Tajikistan and Turkmenistan, HEIs still use Soviet/Russian textbooks translated into national languages. All these factors have a negative impact on the quality of higher education in soil science.
- Armenian HEIs, in particular, seem to have given up most education in soil science. For example, soil science degrees are no longer offered at Armenian National Agrarian University, and only a very few soil science courses are included in the Agronomy curriculum.
- Tashkent State Agrarian University (Uzbekistan) and the National Agrarian University named after Skryabin in Bishkek (the Kyrgyz Republic) are actively cooperating with international development organizations, such as the development agencies from the Republic of Korea and China. This cooperation has made new equipment for soil laboratories and experimental fields available.
- There is only one private HEI organized in accordance with international standards—the Agricultural University of Georgia (Tbilisi)—that

provides education in soil science both in the national language and in English.

- Soil science as taught within organized soil science degrees (undergraduate or graduate) tends to focus on fundamental, rather than applied, soil science. Teaching methods seem to be outdated, with a focus on rote learning, little attention to application, and a general lack of experiential learning.

6.3 Research and Extension in Soil Science

- HEIs and research organizations tend to have low capacity in and poor access to modern tools of soil science, including advanced statistics, spatial science, data analytics, digital soil mapping, remote sensing, and precision agriculture methods. As a result, education, research, and extension in soil science do not address these modern tools.
- There is a general lack of applied soil science research addressing contemporary challenges.
- An annual average of 32 refereed journal articles are published in English about soils from all eight countries. The highest number of publications relate to Kazakhstan or Uzbekistan.
- Research institutions of soil science suffer from funding gaps. Except for some countries, such as Kazakhstan and Uzbekistan, scientific research is mostly financed by donor- supported projects.
- According to interviews with soil scientists from Central Asia, the Kazakh Research Institute of Soil Science and Agrochemistry is the most capable soil science institution within the region in terms of collaborating with the partner's organizations.
- A common concern is the lack of connection between the needs of the private sector and the needs of HEIs and research organizations.

7 Conclusions and Recommendations

7.1 Conclusions

- Soil degradation and food security challenges will continue to exist for the foreseeable future within Central Asia and the South Caucasus.
- Soil science is a critical discipline for tackling food security and environmental challenges within the regions.
- As a profession, soil science is much weaker now than it was during Soviet times.
- The current status of human capital in soil science today ranges from adequate to somewhat inadequate. In no country is the future of soil science bright—many experienced soil scientists will retire within the next decade, and few younger soil scientists are prepared to take their places.
- Across the region, governments have invested little to maintain and strengthen soil science education, research, and extension.
- Across the region, soil science is increasingly seen as a *subject* supporting the disciplines of agriculture, ecology, or environmental science, rather than as a distinct *discipline in its own right*. An appreciation of how soil science can support other disciplines is not unhealthy; however, future development of soils expertise requires that soil science continues to be regarded as a distinct discipline.
- National soil science communities within Central Asia and the South Caucasus are becoming increasingly isolated from each other and from international soil science. Proficiency in the Russian language is becoming less common, and English proficiency is still rare among soil science professionals.

7.2 Recommendations

Human Capital in Soil Science

- Equip a "new breed" of modern soil scientists with knowledge of international soil science and familiarity with modern soil science tools and concepts, including advanced statistics, spatial science, modern analytical methods, data analytics, digital soil mapping, remote sensing, precision agriculture methods, and systems thinking. There is an urgent need for modern soil scientists across the regions.
- Facilitate rejuvenation of the staffs of the soil science research institutions by attracting young scholars from the HEIs.
- Facilitate English proficiency among soil science professionals, especially within HEIs. The vast majority of scientific literature is published in English. Therefore, English proficiency is essential for connecting with the broader world of soil science education, research, and extension.
- Strengthen country and regional soil science societies to encourage cross-fertilization of ideas and capacity building and to facilitate the implementation of international best practices.
- Encourage regional and global connections among soil scientists by organizing regional soil science conferences and facilitating the attendance of scientists at international conferences addressing soil science.
- Strengthen the integration of HEIs and soil science research and extension institutions into the international education and research communities.
- Provide opportunities for soil science professionals to learn modern tools of soil science, such as data analytics, digital soil mapping, remote sensing, precision agriculture methods, and systems thinking.

Education in Soil Science

- Most HEIs are starved for resources. Governments should provide additional resources to enable and facilitate the implementation of international best practices in soil science education and research.
- Soil science is increasingly viewed as a subject supporting agriculture and environmental science. However, to ensure that human capital in soil science is adequate for future needed, soil science should be maintained as a distinct discipline within at least one HEI per country. Both undergraduate and graduate degrees in soil science should be offered.
- Encourage and enable young soil scientists to pursue graduate degrees abroad. Attractive careers in soil science will encourage them to return to their home countries.
- Reform undergraduate soil science curricula according to international standards.
- Empower departments and faculties to create and revise curricula in soil science, with reference to international standards.
- Facilitate benchmarking and evaluating soil science academic programs to international standards. Inviting international soil scientists to review existing academic programs is a good first step.
- Empower soil science faculty to use modern pedagogical methods, such as student-centered learning, in the classroom.
- Provide robust experiential learning opportunities for students in soil science.

Research and Extension in Soil Science

- Most research institutions are starved for resources. Governments should provide additional resources to enable the upgrading of research capacity in soil science.
- Most soil science research institutions need access to modern equipment for soil analysis. Along with modern equipment, adequately trained personnel are essential.
- Refocus soil science research programs toward applied research—that is, problem solving.
- Soil science expertise is critically needed for agricultural extension. Soil science professionals should be trained in extension methodology.

ANNEX 1
Detailed Country Descriptions

Central Asia

Kazakhstan

Despite the oil orientation of Kazakhstan's economy, agriculture continues to play an important role, employing about a third of the country's workforce.

Agricultural enterprises in Kazakhstan consist of three major farm types: large-scale farms (agricultural enterprises), small- to medium-scale farms (individual family farms), and small-scale farms (rural households). Although large-scale farms represent only 15 percent of the farming system in the country, they cultivate up to 50 percent of the agricultural land. About 35 percent of farms in Kazakhstan are represented by small- and medium-scale farms (individual family farms); these farm types cultivate about 30 percent of agricultural land (Mussayeva and Rudert 2016).

Wheat is the major grain crop produced in Kazakhstan and is exported to countries such as the Islamic Republic of Iran, Tajikistan, and Turkmenistan. Today, among processed agricultural products, flour is the major agricultural export product; in recent years, Kazakhstan has joined the top 10 country producers of wheat, flour, and wheat products.

About 60 percent of the agricultural value of Kazakh crops is generated by crop production; the rest of the value is generated by the livestock production sector, which is recognized by the government as having great potential for diversifying the national economy and providing new export opportunities.

Kyrgyz Republic

As in other countries of Central Asia, agriculture in the Kyrgyz Republic is the backbone of the rural economy, engaging 40 percent of the labor force and accounting for 20 percent of GDP (USAID 2018).

In the Kyrgyz Republic, only about 7 percent of the agricultural land is arable and about 45 percent is used as pasture for livestock, which makes animal husbandry a significant part of the agricultural economy. Between 1990 and 2007 the production of wool and meat declined by 70 and 30 percent respectively (The New Agriculturist 2010).

In the process of reforms carried out in agriculture and focused on improving water and pasture management, new agricultural institutions such as Water Users Associations and Pasture Users Associations were established.

The reforms are still underway: registration and demarcation of pastures are in the process and fee collection from pasture users is gradually increasing, while the capacity of the pasture unions to provide advisory services requires further support (World Bank 2011).

Tajikistan

In Tajikistan, the structure of agricultural enterprises consists of four categories of agricultural producers: household plots, individual and family dehkan farms, collective dehkan farms, and agricultural enterprises. Despite the significant presence of kolkhoz and sovkhoz successor enterprises, such as collective dehkan farms and agricultural enterprises, the agricultural sector in Tajikistan is now largely individualized: nearly 65 percent of arable land is in household plots and individual and family dehkan farms (Lerman 2012). However, farmers' specialization within the kolkhoz and sovkhoz enterprises did not prepare them to take on farm business in a market system, therefore requiring agricultural extension and other forms of adult education to play a more important role Tajikistan and other Central Asian countries than in countries that already had this experience (van den Ban 1999).

Agriculture in Tajikistan is a major sector of the economy, both in terms of its contribution to the economy and its impact on employment. The geographic and

climatic environment makes it possible for Tajikistan to produce a wide variety of agricultural products, such as legumes, cotton, vegetables, fruit, grapes, citrus, and more. Pastures and hayfields allow for the development of cattle raising based on natural fodder supplies, which is an important source of livelihoods in rural Tajikistan. According to the FAO, 43 percent of the value of household agricultural production in 2007 derived from livestock products (Sedik 2009).

Despite the country's endowment in natural resources, there are many constraints to the extension of agriculture and increase agricultural production: small-scale producers still lack sufficient technical knowledge and skills and the management of agricultural enterprises is inefficient.

Turkmenistan

Turkmenistan is the second-largest of the Central Asian counties. It has a population is about 5 million and most people live in rural areas, where they mainly work in agriculture. Turkmenistan is an arid country, and about 96 percent of its agricultural land is desert pasture with minor areas of cultivable land. According to an FAO report, the agriculture sector represents 19 percent of GDP in Turkmenistan (FAO 2012). Although agricultural reform was taking place in order to speed up the distribution of land to individual farms and to restructure large collective farms, the state still exercises significant control over the sector. Peasant associations comprising individual agricultural producers, leaseholders, household plots, and *daikhan* farms control about 70 percent of the total land area. About 20 percent of the land is state land stock, while non-agricultural operators use the remaining 10 percent.

Although cotton, which is grown on more than half of the cultivable land, remains the primary export crop, agricultural policy also focuses on grain production, which has resulted in significant increases in non-cotton production.

Livestock is another important part of Turkmenistan's agriculture sector, where rearing karakul sheep is widely popular.

Uzbekistan

Uzbekistan is one of only two double-landlocked countries in the world, and spans more than 1,300 kilometers from east to west. Uzbekistan is bordered by Afghanistan, Kazakhstan, the Kyrgyz Republic, Tajikistan, and Turkmenistan. Its total land area is about 42,000 square kilometers, and only 10 percent of its land area is arable. Including pastures and grazing lands, 63 percent of the country is used for agriculture. Most of the country is a mid-latitude desert, with hot summers and mild winters (CIA 2018).

Agriculture comprises about 20 percent of Uzbekistan's economy, and major agricultural products include cotton, vegetables, fruits, grain, and livestock (CIA 2018). Although the government has taken steps to reduce the area planted with cotton, it remains the country's largest export crop. During 2018–19, the area planted with cotton is projected to be 1.17 million hectares, with a production of 3.8 million bales (USDA-FAS 2018).

Soils of Uzbekistan have been severely degraded. Causes include the diversion of rivers (Amu Darya and Syr Darya) for irrigation, which resulted in the eventual collapse and drying of the Aral Sea. This, combined with poor irrigation practices and inadequate provision for artificial drainage, have resulted in high water tables and salinized soils. In the Fergana Valley, 40 percent of irrigated land is waterlogged and salinized. A total of 21 million hectares of the country is salt-affected—46 percent of total land area (Krasilnikov et al. 2015). Other causes of soil degradation in Uzbekistan include wind and water erosion, depletion of soil organic matter and nutrients, and overgrazing of grazing lands (Krasilnikov et al. 2015). In a region afflicted with serious soil degradation, it is no exaggeration to state that Uzbekistan's soil problems are the most severe.

The South Caucasus

Because of difficult political circumstances and difficult economic conditions existing in the countries of the South Caucasus during the last two decades, less

attention has been paid to this region's soil degradation problem. Those actions taken to combat soil degradation have been for the most part insufficient.

Armenia

Armenia is a landlocked country located within the South Caucasus region. Its area is about 30,000 square kilometers, not including disputed areas. The country is bordered by Azerbaijan, the Islamic Republic of Iran, Georgia, and Turkey. Sixteen percent of the country is arable, and the total land area used for agriculture is 60 percent, including pastures and grazing lands. Almost 60 percent of arable land is irrigated. Agriculture represents 18 percent of GDP and major products include grapes, apricots, vegetables, and livestock. The climate is continental, with hot summers and cold winters (CIA 2018).

Soil degradation in Armenia is mostly due to water erosion. Erosion of sloping lands from overgrazing and poor pasture management is especially severe. Poor soil fertility and the increasing threat from desertification are additional challenges (Suvaryan and Sargsyan 2008). Food security continues to be a challenge in Armenia; as of 2016, 9 percent of children under five years of age were stunted (FAO 2017).

Azerbaijan

Azerbaijan is located in the South Caucasus and borders the Caspian Sea, Armenia, the Islamic Republic of Iran, and Russia. The climate is predominantly arid and semi-arid steppe. Twenty-three percent of the country is arable, and total land area used for agriculture is 58 percent, including pastures and grazing lands. Three-quarters of arable land in Azerbaijan is irrigated. Agriculture is 6 percent of GDP, with grains, fruits, vegetables, cotton, tobacco, and livestock as major products. Agriculture's contribution to GDP is significantly lower than it is in Armenia and Georgia, largely because of Azerbaijan's oil production (722,000 barrels/day) (CIA 2018).

Similar to neighboring Armenia and Georgia, the soils of Azerbaijan suffer from erosion, nutrient depletion, and secondary salinization. More than 27 percent of arable land contains salt-affected soils (Krasilnikov et al. 2015). Some measures of food security are better in Azerbaijan than its neighbors. Undernourishment was less than 2.5 percent in 2016, compared to 7.0 percent in Georgia. Only 4 percent of the population lives on degraded land, compared to 10 percent in Armenia. However, childhood stunting (for the population under five years) is the highest in the South Caucasus, at 17 percent (FAO 2017).

Georgia

The Republic of Georgia is a Eurasian country of the Caucasus region located at the crossroads of Western Asia and Eastern Europe. Georgia borders the Black Sea on the west, and shares a border with Armenia, Azerbaijan, Russia, and Turkey. Its climate ranges from continental in the east to Mediterranean in the west. Only 6 percent of the country is arable, and total land area used for agriculture is 35 percent, including pastures and grazing lands. The remainder of the country is sloping, forested, or otherwise unsuitable for agriculture. Agriculture comprises 10 percent of GDP, with grapes, fruits, vegetables, and livestock as major products (CIA 2018). The country faced a serious economic crisis during most of the 1990s, and persistent poverty still prevails, particularly in its rural areas, where it is caused by decreased agricultural production.

Thirty-five percent of farmland in Georgia is degraded as a result of soil erosion, loss of vegetative cover, mining, and secondary salinization. Up to 70 percent of Georgian soils are significantly depleted of nutrients (World Bank 2015). Undernourishment, at 7 percent of the population, is the highest among South Caucasian countries. However, only 2 percent of Georgia's population lives on degraded lands (FAO 2017). Georgia regularly experiences drought during the growing season, which also leads to acceleration of soil degradation.

ANNEX 2
On-Site Or Online Interviews With Key Institutions

Country	Date	Institution
Armenia	July 24, 2018	Armenian National Agrarian University
		Scientific Center for Soil Science
		Ministry of Agriculture, Dept. of Land Use and Reclamation
	July 27, 2018	ICARE-International Center for Agribusiness Research and Education
		Ministry of Nature Protection, Bioresources Management Agency
	September 18, 2018	World Bank Country Office, Armenia
Azerbaijan	July 19, 2018	Baku State University, Faculty of Ecology and Soil Science
		Ministry of Agriculture, Soil Utilization and Control Dept.
	July 21, 2018	National Academy of Science, Soil Science and Agrochemical Institute
Georgia	July 23, 2018	National Academy of Sciences
		Georgian Farmers Association
		Parliament of Georgia, Agrarian Issues Committee
		Ministry of Environmental Protection and Agriculture
	July 24, 2018	International Coordination Center for Farmers' Education and Training
		Research Center of Agriculture and Soil Fertility Research Service
		Agricultural University of Georgia, Inst. of Soil Science
Kazakhstan	June 11, 2018	S. Seifullin Kazakh Agrotechnical University
		Ministry of Agriculture
		Republican Scientific-Methodological Center for Agrochemical Services, Ministry of Agriculture
	June 12, 2018	Kazakh Scientific Research Institute of Soil Science and Agrochemistry named after U. U. Uspanov
		South Kazakhstan Hydrogeology and Melioration Expedition (HGME), Committee on Water Resources, Ministry of Agriculture
Kyrgyz Republic	June 7, 2018	Kyrgyz National Agrarian University named after K. I. Skryabin
		Republican Soil Agrochemical Station, Ministry of Agriculture, Food Industry and Melioration of the Kyrgyz Republic
		Institute of Biology & Pedology of the National Academy of Sciences; Ministry of Agriculture, Food Industry and Melioration of the Kyrgyz Republic
		Rural Advisory Services, Chui Talas
	June 8, 2018	Training, Advisory and Innovation Centre (TAIC)
		Kyrgyz Soil Science Society
		Irrigation Institute, Ministry of Education
		Kyrgyz Research Institute for Agriculture, Ministry of Agriculture, Food Industry and Melioration of the Kyrgyz Republic

ANNEX 2On-Site Or Online Interviews With Key Institutions

Country	Date	Institution
Tajikistan	June 4, 2018	Tajik Academy of Agricultural Sciences
		Tajik Soil Science Research Institute
		Tajik Soil Science Society
		Ministry of Agriculture of the Republic of Tajikistan
	June 5, 2018	National Association of Dehkan Farms of the Republic of Tajikistan
		Tajik Agrarian University named after Shirinsho Shotemur
		Institute FAZO
		Committee for Environmental Protection under the Government of the Republic of Tajikistan
Uzbekistan	July 16, 2018	Tashkent University, Dept. of Soil Science
		State Agency for Land Management, Institute of Soil Science
		UZGIP Research and Design and Surveying Institute
	July 17, 2018	Ministry of Agriculture
		National Academy of Sciences, Scientific Production Center for Agriculture
		National Agrarian Univ., Dept. Soil Sci. and Agrochemistry
		Farmers Union Council
	July 18, 2018	Tashkent Institute of Irrigation and Agricultural Mechanization (TIIAME)
		ICARDA Regional Office for Central Asia and South Caucasus
		Central Asia and the Caucasus Association of Agricultural Research Institutions (CACAARI)
		National Extension Center for National Agrarian University
	August 27, 2018	World Bank Uzbekistan Country Office

ANNEX 3:
Survey Form for Soil Scientists in Central Asia and the South Caucasus

Online survey "Human capital in soil science in Central Asia and South Caucasus"
Name:
E-mail:
Gender:
Date of birth:
Country:
Permanent address (city):
Organization:
Job position:
Work experience in soil science:
Background:
Attended from:
Name, place and country:
Academic degree:
Could you please provide an assessment of the state of soil science in your country?

Your recommendations for improving the state of soil science in your country:

Could you please provide an assessment of the level of professional training of soil scientists in your country?

Your recommendations for improving the quality of training of soil scientists in your country:

Where do the soil scientists more commonly work?

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Lomonosov Moscow State University

Eurasian Center for Food Security

Lomonosov Moscow State University

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