David Dent *Editor*

Soil as World Heritage

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Preface

The symposium *Soil as World Heritage* was held in the spring of 2012 to celebrate the half century of systematic field experiments at Balti, in the north of Moldova. The experiments monitor and evaluate the impact of crop rotations, monoculture, fallow, fertilization, tillage and irrigation on crop yields and soil fertility. The proceedings highlight the importance of such experiments for understanding the consequences of current farming practices, especially on the famous black earth or chernozem. But there is more.

Between 1965 and 1980, the *green revolution* increased crop yields two- to threefold, transcending differences in soils and climate. For a generation, food production was carried ahead of population growth, and political attention was turned away from land, food and agriculture. Policymakers today face new challenges and bigger challenges:

1. Burgeoning demand means that, by 2050, food production will need to be 70 % greater than now – double in developing countries. All this production must come from the same land and water resources or, if present trends continue, much less; there are no great reserves to draw on, the area under cereals peaked in the 1980s and diversion of arable to biofuel production intensifies the pressure.
2. We have passed peak soil. On top of historical land degradation, today's agricultural practices are driving land degradation, water shortage and contamination, loss of biodiversity and climate change. The last quarter century has witnessed degradation of one-quarter of the land surface; every continent and every biome is affected. The issue goes beyond mismanagement: tracts of the best land are being lost every year to cities and connecting infrastructure, and it appears inescapable that rising sea level will flood great cities and productive farmland.
3. The food system is unsustainable. The green revolution depended on cheap fuel, fertilizer and irrigation applied to new, responsive crop varieties. Fuel and fertilizer are no longer cheap, water resources are overcommitted and crop yields have levelled off – in some places they are falling.

4. Climate change is driven both by burning fossil fuels and by the insidious destruction of soil organic matter – yet the soil is the only buffer against climate change that we know how to manage. The symposium highlights the effects of drought on crop yields across southern and eastern Europe; yet more dramatically, by 2050, half of what is now India's high-potential wheat-growing land is likely to be heat-stressed, short-growing-season cropland.

One response is the international land grab where the power lies with the big players and which does nothing to help the global situation. Contributions to this symposium indicate a sustainable alternative that combines proven practices of conservation agriculture or ecological agriculture that retain and rebuild the soil with precision farming that tailors crops and operations to the natural variability of the landscape. This is high farming that demands high knowledge at the policy level and in the field – knowledge that depends on better information on land resources and relearning much that has been forgotten. We have to grow both the soil and the knowledge.

Chernozem is, simply, the best arable soil in the world. Historically, it has been the breadbasket of the Old World and the New. The chernozem of the Balti steppe was also at the heart of the foundation of soil science. Dokuchaev visited this very place, collecting material for *Russian chernozem,* and his first account is a concise statement of the principles of a new science. He wrote: 'The chernozem seemed to me, in 1877, so typical in its thickness, structure and humification that I called it first class. The analysis showed the content of humus was 5.718 %'. That soil now, under the plough, has nowhere more than 3.8 % humus and chernozem everywhere have lost 20–70 % of the humus that binds the soil together and created what appeared to be inexhaustible fertility. On present trends, by 2026, the humus content of chernozem across the country will be down to 2.5–3 %, and approaching a catastrophic shift to a different and unstable ecosystem; the black earth will turn to dust as it did in the prairies of America and Canada in the 1930s.

Agricultural practices are driving global warming, leaching of nutrients, pollution of water resources and diversion of rainfall away from replenishment of soil and groundwater to destructive runoff. These are pressing issues for our generation and will press harder on future generations. Long-term field experiments, and the scientific skills and experience that they nurture, will be increasingly valuable as a foundation and a focus for interdisciplinary teams of specialists studying the effects of farming practices on the soil and on both above- and below-ground components of flora, fauna and microorganisms. Experimental data built up over the last 50 years demonstrate the damage caused by human activity to the productivity and integrity of chernozem and, also, ways to restore its fertility.

For all these reasons, the chernozem of the Balti steppe under the long-term field experiments has been proposed as the first World Heritage Site for soil and soil science as *an outstanding example of human interaction with the environment that has become vulnerable under the impact of irreversible change, of significant ongoing ecological and biological processes in the evolution and development of terrestrial ecosystems and communities of plants and animals, and containing the* *most important natural habitats for in situ conservation of biological diversity, including threatened species of outstanding universal value.* By safeguarding this unique ecosystem and testimony to civilization, we may work towards sustainable development of society – and agriculture in particular. The ongoing scientific work is also a foundation for public appreciation of soils and soil science which is critical for wise policy and management.

These proceedings include contributions from 14 countries under headings: *The Soil and Environment*, *Soil Fertility: Lessons from Long-Term Field Experiments*, *Different Ways of Doing Things*, and *Soil Policy and Communications to Decision Makers.* On the last topic, there has been much wringing of hands by the scientific community about the lack of effective action to arrest land degradation, loss of biodiversity and climate change. Inaction is not due to lack of information: inaction stems from a lack of acceptable courses of action. If acceptable, and effective, courses of action are to be developed, the scientific community must involve itself in practical and political developments – even though this means venturing to the exposed frontiers of its own knowledge and experience. Therefore, at the request of the President and Government of Moldova, our communications to decision makers include recommendations of all the participants. These recommendations include definition of a new research thrust to support more sustainable land use through crop rotations that can be commercially viable, self-sufficient in energy, and which restore the stocks of soil organic matter; and a soil resolution that may serve as a basis for legislation. Important and achievable recommendations include:

1. Initiatives have to be within the framework of national policy for food and water security. Our first recommendation is to review this policy in the light of present knowledge of the land and develop *a national program for food and water security and safety worked out at local, regional and state level, including support for or creation of markets for the required production and services such as water management and carbon sequestration.*
2. Knowing what you want to achieve, it may be useful to set out ground rules in the form of a soil law. This is our second main recommendation: *adoption of a soil law to secure the services provided by the soil to society and the environment. This law should be the basis for allocation of payments or other incentives necessary to achieve the required protection of soil services.*

   Examples of incentives include *green water credits* paid to farmers for water management services (in the shape of approved soil water management and soil conservation practices). This does not require the government to find new money; credits are paid for by the direct beneficiaries of this service, the water users. Also, we may draw on EU experience of integrating soil protection within the Common Agricultural Policy; to receive support from the EU budget, farmers should respect standards set nationally to protect the soil against erosion, maintain soil organic matter and soil structure and avoid degradation of habitats and landscape features.
3. *Application of such policy and compliance with its conditions requires revitalized state services, working in partnership with land users, to elaborate*

whole-farm and community plans for rational land use, to provide on-farm support for the adoption of best practice and to monitor the state of soil and water resources. This recommendation does require new money!

4. The system of landholding goes against the requirement of sustainable land management, but this is not the time for another upheaval. We recommend evolution of the system towards something better fitted to the task. Possibilities include extension of the period of leasehold to, at least, the length of a sustainable crop rotation (say 7 or 8 years) or, better allow 99-year leases so that the leaseholder has incentive to take good care of the land. The final, easy-to-implement recommendation is: *support for cooperation between individual farmers for purchasing inputs, marketing produce and services, soil and water conservation at the landscape scale, and mutual exchange of know-how and support for services to cooperatives by contractors, especially for the purchase of new equipment needed for conservation farming*.

Norwich, January 2013 David Dent

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Part III Different Ways of Doing Things

Role of Honour: those whose time and efforts have established and maintained the Selectia long-term field experiment in crop rotations and continuous monocultures

Years	Head of the Department	Years	Scientists in charge	Years	Technical workers	Years	Workers
1946–1949	Mihail Sidorov	1945–1960	Nicolae Lebedev	1960–1967	Lidia Necrasova	1956–1968	Andrei Doroftei
		1954–1961	Vasile Cazanji	1962–1996	Lidia Cuţulima	1961–	Ana Meacicova
1950–1956	Iosif Liberştein	1964–1979	Iurie Bondarenco	1968–1977	Vera Gulita	1965–1997	Nina Buţenco
		1963–1989	Gheorghe Şonţu	1970–2002	Dmitri Gasnaş	1992–1995	Alexandru Bodnari
1956–1984	Petru Chibasov	1970–	Lidia Bulat	1971–	Lidia Camennaia	2000–2006	Anatol Frasiniuc
		1984–	Boris Boincean	1964–1978	Maria Cozac		
1984–1992	Cozma Cibotari	1991–1994	Victor Garaşchiuc	1979–2002	Maria Revenco		
1992–	Boris Boincean	2002–	Mihail Bugaciuc	1993–	Tanea Bugaciuc		
		2002–	Vadim Cuzeac	1996–2000	Eudochia Labutina		
		2008–	Marin Cebotari	2011–	Andrei Negrescu		
				2011–	Marina Iluşca		

Those whose time and efforts have established and maintained the Selectia long-term field experiment on fertilization systems in crop rotations

Head of the Department	Scientists in charge	Years	Technical workers and years	Workers
Matina M.S. (1945–1970)	Nica L.T.	1957–1970	Popa T. (1970–2006)	Vaţetco R.P. (1967–2002)
Naconecinîi Zinaida I. (1964–1992)	Nichitchin B.G.	1954–1980	Ranga I. (1970–1978)	Ţurcan O. (1984–2005)
Boincean Boris P. (1991–)	Iachimov S.V.	1970–1976	Cîşlaru Z. (1970–)	Corobeinicov E. (1975–1996)
	Revenco E.I.	1972–1979	Barac L. (1970–1994)	Ivanov A. (1967–1981)
	Taran M.G.	1970–1976	Grigorenco O. (1968–1976)	Roşca D. (1983–1987)
	Barbuţă D.N.	1979–1990	Babin G. (1959–1976)	Anţeperovici S. (1975–1987)
	Crasnojan V.D.	1981–1993	Cucu L. (1968–1977)	Anţeperovici L. (1975–1987)
	Stadnic S.S.	1981–1997	Colibaba S. (1973–1979)	Calistru M. (1984–1987)
	Bolduma A.	2002	Cricsfelid C. (1972–1980)	Melnic N. (1976–1988)
	Zbanc E.	2007–2010	Chiaburu V. (1984–1988)	Moldovan V. (2001–2005)
		2009	Lupuleac G. (1975–1977)	Mereuţă T. (2001–2005)
			Dochienco L. (1972–1974)	Cozionova N. (2002–2004)
			Reaboi V. (1984–2000)	Damian R. (1985–1987)
			Botnariuc B. (1986–1992)	Şarîghina R. (1977–1992)
			Chilimova E. (1983–1988)	Micşhanscaia E. (1975–1987)
			Saico L. (1981–1984)	
			Biciuşca M. (1984–1985)	

Volcov A. (1996–1998)
Mahu L. (1975–1981)
Fediuc C. (2002–2008)
Gavriliuc N. (2000–2004)
Balan L. (1981–1983)
Ceaglîc S. (1975–2001)
Ghiţan G. (1956–1970)
Halfina P. (1973–1975)
Gutman F. (1982–1996)
Socoliuc I. (1984–1987)
Voitic Z. (1983–1985)
Ianuşchevici E. (1985–1991)
Danilchina I. (1978–1980)
Secrieru I. (2006–)
Bodiu N. (2011–)

Those whose time and efforts have contributed to the establishment and maintenance of the Selectia long-term experiment on irrigation

Years	Head of the Department	Years	Scientists in charge	Years	Technical workers	Years	Workers
1968–1996	Mihalcevschi V.D.	1968–1970	Perju V.E.	1968–1971	Buchinschi I.G.	1968–1975	Lupu M.M.
1997–2001	Hropotinschi P.	1968–1973	Geletchi V.S.	1968–1970	Urman P.M.	1968–1976	Ciolacu M.I.
2001–	Boincean B.P.	1970–1977	Urman P.M.	1969–1974	Poblotchi A.G.	1970–1976	Melnic N.N.
		1974–1976	Ilienco G.	1972–1977	Conicova N.A.	1970–1980	Movilă P.I.
				1973–1996	Martea M.P.		
		1974–2000	Pobloţchi A.G.	1974–1976	Bucatari I.I.	1972–1973	Martea M.P.
		1977–2000	Conicova N.A.	1976–1977	Ungureanu V.	1977–1982	Guţu I.I.
		1980–1989	Tcacenco V.I.	1976–1977	Chiaburu V.	1983–1990	Dranca A.A.
		1995–1997	Hropotinschi P.M.	1977–1981	Chitic I.V.	1983–1990	Dranca O.L.
		1995–	Ungurean A.I.	1977–1979	Mitrofanova L.I.	1985–2006	Golbur L.M.
		1996–	Martea M.P.	1980–1988	Rudniţchi D.N.	1995–2003	Surcov A.V.
		2001–2005	Hropotinschi P.M.	1980–1989	Tcacenco T.G.	1996–2004	Dolghier A.C.
				1981–1983	Bejenari V.N.	1996–2001	Rotari M.
				1984–1988	Moscalenco M.G.	1999–2006	Furtună T.G.
				1984–1989	Erenciuc I.V.	2004–2009	Aftanas I.
				1984–1990	Temciuc C.I.	2004–	Savca N.V.
				1984–1996	Ponomarenco V.M.	2008–2010	Tambur G.G.
				1995–2006	Statna M.N.	2008–2010	Fostei N.P.
				1997–1998	Punga V.		
				2009–2010	Rusnac S.		

Part I
The Soil and Environment

Chapter 1
Chernozem: Soil of the Steppe

A. Ursu, A. Overenco, I. Marcov, and S. Curcubăț

Abstract Chernozem is the predominant soil of Moldova and the country's greatest natural treasure. Its profile is very thick, well humified and well structured – properties inherited from the steppe. Only grassland with its many-branched and deeply-ramified root system is able to produce abundant organic matter and humification throughout the solum. The underlying horizon, enriched in secondary carbonates, is a marker of the soil water regime that determines the different subtypes of chernozem. From north to south, less and less water percolates through the profile; in phase with the water regime, *Leached chernozem* gives way to *Typical chernozem* which, in turn, gives way to *Carbonate chernozem.* All chernozem share the thick, black, granular topsoil – remarkable for its fertility and resilience – but more than a century of cropping has degraded the chernozem; even where the soil profile is intact, it has lost half of its native humus and requires different and better treatment if its productivity is to be sustainable.

1.1 Introduction

Soils constitute the greatest natural treasure of the Republic of Moldova. The predominant soil is chernozem – described by the founder of the soil science as 'the king of soils'. Its remarkable fertility is determined by its rich composition, unique conservatism and resilience to degradation – even after being worked for centuries. Over millennia, chernozem accumulated and preserved a great store of energy and nutrients in the form of humus which stabilises the famous granular structure and endows the soil with great permeability and available water capacity. The soil is easily worked, maintains its structure and resists erosion by wind and

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water. These attributes were soon appreciated wherever the chernozem is found, encouraging unlimited exploitation for agriculture but, under intensive exploitation, even the chernozem has yielded to the processes of degradation.

1.2 Soil-Forming Processes

Chernozem was formed during a long period of soil genesis in the steppe and forest-steppe zones under herbaceous vegetation rich in grasses (Fig. 1.1). According to some mineralogical estimates, chernozem pedogenesis lasted for hundreds of thousands of years (Alekseev 2003).

Chernozem is the result of synthesis and accumulation of enormous quantities of organic matter subjected, partially, to mineralisation and, partially, to humification. This organic matter, conserved as humus and acting together with the mineral parent material, provided conditions for formation of complex, organo-mineral calcium humate that determines the essential character of chernozem – its blackish colour – and, together with the root system of the steppe vegetation, creates its strong granular structure. Humus is found throughout the solum, which may be 80–100 cm thick (Fig. 1.2), although the amount decreases with depth. Such a deeply humified and well-structured soil can be formed only by steppe vegetation, which develops a very deep and branching root system. Under forest, by contrast, herbaceous vegetation is ephemeral and the forest litter and perennial root systems do not create deeply humified soils.

The temperate seasons drive seasonal and annual rhythms of vegetation. Organic matter produced by plants (the primary producers) serves as food for animals and is

Fig. 1.1 Feather grass steppe

Fig. 1.2 *Typical chernozem*, moderately humified

further comminuted and decomposed by the soil fauna and microorganisms, ensuring the annual and multiyear cycling of organic matter (and carbon). The balance is conditioned by the amount of primary organic matter and amount of synthesised humus. Under natural steppe ecosystems, the balance is positive; humus and biologically sequestered mineral elements extracted from the regolith accumulate up to a point that may be called a *climax* state, when the amount of humus decomposed to its initial components (water + CO_2 + minerals) becomes equal to the newly synthesised humus.

All chernozem share the thick, black, granular topsoil. Within the chernozem zone, lower taxonomic units may be distinguished by attributes conditioned by variations of intrazonal pedogenetic factors. Climate plays a decisive role; the diagnostic horizon for division of chernozems into subtypes is the subsoil horizon of secondary carbonates (CSRM 1999) which is conditioned by the water regime – *percolative* in the north, *non-percolative* in the south. The depth of the carbonate horizon is an easily identified characteristic that indicates other soil attributes conditioned by geographical position and climate – notably humus content, structure and potential productivity. The more percolative the water regime, the more deeply carbonates are leached from the soil profile. The *Typical chernozem*[1] is the characteristic soil of the steppe, having all the specific characters of the type: a thick

[1] In the *World reference base for soil resources 2006* (IUSS 2006) Typical and Leached chernozem key out as *Haplic chernozem,* Carbonate chernozem *as Calcic chernozem. Luvic and Vertic chernozem* are as in WRB.

Table 1.1 Physicochemical characteristics of a Typical chernozem, moderately humified

Depth, cm	Humus %	$CaCO_3$	pH	Exchangeable cations, me/100 g: Ca^{++}	Mg^{++}	∑
0–10	3.9		7.1	29.7	5.3	34.9
30–40	3.7		7.2	30.4	5.1	35.4
50–60	2.3		7.5	28.5	4.9	33.3
70–80	1.4	3.8	8.2			
90–100	1.0	8.1	8.6	26.3	7.7	30.1
110–120		13.7	8.6			

solum, well humified, granular structure and with the carbonate horizon between the A and B layers. The solum of *Leached chernozem,* under a percolative regime, is leached of carbonates which occur only below the B horizon; the *Carbonate chernozem*, under a non-percolative regime, contains carbonates throughout the soil profile, including the topsoil.

Chernozem includes two further subtypes with a transitional character. *Luvic chernozem* is formed at the furthest limit of the type under mixed oak forest and borders with the *grey* soil type; it retains all the attributes conditioned by steppe vegetation but adds some specific characters – a powdering of silica on the structural elements of the upper horizon and clay accumulation in the lower part of the solum. Its genesis might be explained by forest invasion into the steppe. Another opinion is that this subtype is formed in rare cases where woodland has been succeeded by steppe grassland. Both may be correct. Within the chernozem zone, *Vertisols* occur as a lithomorphic soil type on heavy-textured, illite-montmorillonite parent material. Adjacent to Vertisols, on the same clay parent material, the transitional subtype of *Vertic chernozem* may be found. Its topsoil is typical for chernozem but the B horizon exhibits the vertic characteristics of coarse polyhedral structure with slickensides.

The chernozem of Moldova is almost entirely cultivated and has been for centuries. For all its resilience, over time the topsoil has lost its granular structure, the humus content has decreased, nutrient reserves accumulated over millennia have been depleted and the topsoil has been compacted and exposed to erosion by rain-splash and runoff. There is practically no virgin chernozem left in former steppe regions, so there is no way to check its original composition, except for Luvic chernozem that is still preserved under forest. Analyses made in the past show that the humus content of Typical chernozem exceeded 5–7 % (Dokuchaev 1883, 1900; Krupenicov 1967; Krupenicov et al. 1961; Ursu 2005). Currently, the arable Typical chernozem of the Balti Steppe contains 3.9 % humus (Table 1.1) and the thickness of the solum (with humus content >1 %) is about 80 cm.

The same soil under an oak shelterbelt, 60 years old, has 6.9 % of humus in the topsoil. It is difficult to explain such increase within 60 years; possibly, the soil sample collected in the shelterbelt contained organic residues that are difficult to remove, as Dokuchaev (1883) mentioned with reference to a soil sample collected from the forest in Cuhuresti. Nevertheless, the increase of organic matter content in

Table 1.2 Physicochemical characteristics of a Leached chernozem

	Humus	$CaCO_3$		Exchangeable cations		
				Ca++	Mg++	∑
Depth, cm	%		pH	me/100 g		
0–20	4.6		6.6	26.8	9.6	36.4
30–40	4.5		6.8	26.4	9.6	36.0
45–55	3.6		6.9	25.2	10.8	36.0
60–70	3.1		7.3	24.8	10.4	35.2
70–80	2.3		7.3	23.6	11.6	35.2
80–90	1.8	2.8	7.4	23.2		33.2
110–120	1.2	11.9	7.8	22.8	9.6	32.4

the surface layer of chernozem under a grass sward and forest conditions suggests a real possibility of restoring the humus balance.

Regional variants of Typical chernozem may be distinguished according to humus content: in forest-steppe and the Balti Steppe, the humus content of the plough layer exceeds 3.3–3.5 %; in the Southern Plain the range is 2.5–3.2 % – this lower humus content is considered to be an indicator of the dryer climate (Krupenicov and Ursu 1985; Ursu 2006). So, within the Typical chernozem subtype, two groups are distinguished – *moderately humified* and *weakly humified*; the former borders with Leached chernozem, the latter with Carbonate chernozem. However, assigning quantitative indices of humus content to these two groups is problematic because humus content can be conditioned by texture; a clayey *Typical weakly humified chernozem* may have a higher humus content than a loamy *Typical moderately humified chernozem*. Virgin chernozem of practically all subtypes can be characterised as *humified*; likewise chernozem under forest plantations, etc. which may be recovering their original humus status.

On the Balti steppe and the hilly regions of forest-steppe, Leached chernozem occurs alongside Typical chernozem; there is no clear transition between the leached and typical subtypes so the boundary between them is arbitrary. The former occurs at higher elevation; it has a thick, well-humified and deeply structured solum (80–120 cm) with a high base saturation but without carbonates, which appear below 80–85 cm (Table 1.2). The leached subtype is more humified and with a thicker solum than the typical; the humus content of the arable layer is 4.6 %, decreasing gradually to 1.2 % at 110–120 cm.

The Carbonate chernozem subtype, formed under xerophytic steppe conditions, presents the southern boundary of the type.

1.3 Conclusions

The chernozem is the outstanding natural wealth of the country. It created itself over many thousands of years and accumulated enormous reserves of energy and nutrients in the form of humus – about 1 billion tons in Moldova alone. This ‘king of soils' has many attributes favourable to agriculture and great natural fertility. But it is not used properly; it is being degraded and destroyed. The chernozem deserves better; it deserves respect and requires good husbandry and efficient protection. Soil science has developed concepts and practical measures that enable sustainable use of chernozem – but these measures need to be implemented.

Each generation may and should be able to use the soil for food production. At the same time, it is obliged to maintain and pass on this treasure to future generations.

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Chapter 2
The Quality of Moldovan Soils: Issues and Solutions

S. Andrieş, V. Cerbari, and V. Filipciuc

Abstract From the economic point of view, soil is Moldova's most valuable natural resource. Maintaining the productive capacity of the soil over the long term and increasing its fertility to ensure food security should be primary goals of the whole nation. Soil investigations are aimed at solving the problem of maintaining the quality and production capacity of agricultural land in the face of high rates of soil degradation. Annual direct and indirect losses amount to 4.8 billion lei, including 1.85 billion lei from the irreversible loss of 26 million tons of fertile topsoil by erosion from slopes; 878 million lei from the complete destruction of soil cover by landslides, ravines and excavation for social needs; and 2.07 billion lei in lost agricultural production. Irreversible losses as a result of total destruction of soil cover over about 30 years amount to about 36.5 billion lei.

Problems and solutions for the protection, improvement and rational management of agricultural soils are listed in state programs elaborated with support of the Nicolae Dimo Institute.

2.1 Introduction

As support and living environment for people, plants and animals, the soil cover is the main part of Moldova's natural capital but it is finite and, on the human time scale, non-renewable. Soil is the wealth of the entire nation and should be used in the national interest in accordance with the law, regardless of land ownership. Proper management of soil resources is a primary social issue; the needed increase of agricultural production can be achieved only through rational use of soil resources.

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We need to know the productive capacity of the arable land and its resilience under existing farming systems. Unfortunately, the quality of our arable is far from satisfactory; areas affected by erosion and landslides continue to expand; processes of humus loss, structure deterioration and compaction, salinity and sodicity, waterlogging and drought are intensifying – leading to breakdown of biophysical cycles, soil deterioration and loss of fertility.

Food and agriculture contribute 15–20 % of GDP. They depend on soil resources for agricultural and livestock production, environmental services and social welfare, especially in rural areas. Therefore, proper management of soil fertility is a primary social issue (National Program for Soil Fertility 2001, 2002, 2004).

State programs for soil conservation and sustainable use and management require land-use planning for multiple functions. Here we summarise the results of 60 years of soil investigation by the Nicolae Dimo Institute, the Design Institute for Land Management and other investigations in soil science conducted in scientific institutions within the country.

2.2 Condition of the Land Resource

The land resource of the Republic of Moldova comprises 3,384,600 ha of which farmland occupies 2,498,300 ha (73.8 %) including arable, 1,812,730 ha (72.6 %); perennial crops, 298,780 ha (12.0%); meadows, 352,550 ha (14.1 %); and fallow, 14,210 hectares (0.4 %). Farmland amounts to only 0.5 ha per caput including 0.4 ha of arable. About 1,877,100 ha is held by 1,310,000 private landowners with the average holding of 1.4 ha divided between two and five individual plots (Agency for Land Relation and Cadastre 2010).

Scientifically blind land reform fragmented holdings and created up-and-down slope alignment of plots that has not helped sustainability, fertility or farm production. The weighted average *bonitat* rating of farmland in 2010 was 63 points, yielding a modest 2.5 t/ha of winter wheat, whereas in the 1970s the rating was equal to 70 points. The current value of one *bonitat* point in terms of agricultural production is $8/ha/year, so recent losses as a result of depreciating soil quality amount to $56/ha/year, adding up to $105,420,000 per year for all farmland.

2.3 Land Evaluation and Soil Quality Information System

Land evaluation at the broad scale is the responsibility of soil scientists in the Design Institute for Land Management (DILM). Soil mapping still follows procedures drawn up prior to the land reform – which do not correspond to the current situation. A better identification of land quality problems and solutions and planning of measures to combat land degradation require periodic land evaluation and the creation of an electronic soil quality information system. A correct cadastre of soil quality requires, in turn: (1) improvement of the soil survey investigation system and regular re-evaluation of the entire country every 20 years and (2) improvement of soil classification and soil evaluation methods. A prototype methodology for soil investigation and electronic soil quality information system developed by the Nicolae Dimo Institute and the Agency for Land Relation and Cadastre of Moldova has been tested at the community level for 17 villages in Teleneshti district (Cerbari et al. 2010).

2.4 Soil Degradation

Krupenikov (2008) describes in detail five types and 40 forms of soil degradation that lower the productive capacity of the land and, in the worst case, completely destroy the soil cover. Erosion by runoff water affects 2.5 million ha, loss of soil nutrients also 2.5 million ha, salinity and sodicity affect 220,000 ha, landslides 81,000 ha and nearly all arable land suffers from loss of soil structure and secondary compaction (Tables 2.1 and 2.2).

Soil erosion is the main agent of land degradation and contamination of water resources (Nour 2001). The affected area increased from 594,000 ha in 1965 to 878,000 ha at present – an average annual increase of more than 7,000 ha involving a reduction of productivity of some 20 % in the *slightly eroded* category, 40 % for

Table 2.1 Soil quality indices

Quality indices	Index appreciation: Optimum/allowable limit	Index appreciation: Actual	Actual index condition
Erosional			
Soil loss t/ha	5	15–20	Extremely high
Humus loss kg/ha	70	700	Extremely high
Nutrient loss (NP) kg/ha	10–12	50	High
Agrophysical			
Soil structure (sum of aggregates 10–0.25 cm) %	60–80	40–45	Unsatisfactory
Bulk density g/cm^3	1.10–1.22	1.25–1.30	Moderately compacted
Porosity %	50–55	45–50	Low
Infiltration speed mm/h	42–70	20–30	Very low
Agrochemical			
Humus content % at 0–30 cm	>4	80% of arable land has less than 3% humus (low content)	
Humus balance t/ha/year	Steady or positive	−0.7	Negative
Optimum P content at 0–30 cm mg/100 g soil	3.0–4.0	60 % of arable has low soil P	
Nutrient balance (NPK) kg/ha	Steady or positive	−130 to −150	Extremely negative

Table 2.2 Land degradation in Moldova, after National Program for Soil Fertility (2002)

No.	Factors and forms of degradation	Affected farmland, 1,000 ha	Damage, US$1,000 Annual	By soil loss
1	Sheet and rill erosion	878	221,365	–
2	Gully erosion	8.8	7,622	370,594
3	Landslides	24.1	–	1,014,923
4	Complete destruction of soil by excavation	5	–	210,565
5	Secondary compaction	2,183	39,730	–
6	Salinity in gley soils on slopes and in depressions	20	3,640	–
7	Salinity in alluvial soils	99	5,405	–
8	Sodicity in steppe soils	25	1,820	–
9	Humus loss	1,037	18,873	–
10	Low/very low mobile phosphorus content	785	28,574	–
11	Salinity and compaction under irrigation	12.8	699	–
12	Other factors	1,258	108,751	1,722,422
Total		–	436,479	3,318,504

moderately eroded and more than 50 % for *highly eroded* soils. Sheet, rill and gully erosion are widespread; over the period 1911–1965, the area of gullies doubled from 14,434 ha to 24,230 ha. After 1965, some of the gullied land was afforested and some areas were levelled, reducing the gullied area to 8,800 ha in 1999, but in 2005 the recorded area was 11,800 ha thanks to cessation of controls and feckless management of the land over recent years.

Landslides: Some 800,000 ha of land is affected by inactive landslides that are prone to reactivation (*Ecopedological Monitoring* 1996; Cerbari 2011a); the area of farmland affected spread from 21,200 ha in 1970 to 24,500 ha in 2010. The main preventative and control measures are diversion of runoff water, drainage, land levelling and afforestation. These are costly but it is more costly to neglect and abandon affected areas.

Humus loss: Humus is a prime index of soil fertility, determining agrophysical, agrochemical and agrobiological soil attributes. It has been established by experiment that increasing humus content by 1 % yields 1.0 t/ha of maize or 0.8 t/ha of winter wheat (Andries 2007). Under the plough, Moldovan soils have lost about 40 % their original humus reserves. Over the last 15 years (1994–2009), the application of farmyard manure has decreased 60-fold; the area sown to perennial grasses decreased 4–5-fold; and over large areas crop residues are simply burnt in the fields. As a result, the soil's humus balance is negative (−0.7 t/ha/year and, with losses by erosion, −1.1tonnes); every year, our arable loses some 2.4 million tons of humus. Increased input of organic matter is entirely possible using crop rotations with more land under perennial and annual legumes, grasses and green manure and by application of farmyard manure.