91850

Ukraine: Soil fertility to strengthen climate resilience

Preliminary assessment of the potential benefits of conservation agriculture

FAO INVESTMENT CENTRE

DIRECTIONS IN INVESTMENT

FAO INVESTMENT CENTRE

Ukraine: Soil fertility to strengthen climate resilience

Preliminary assessment of the potential benefits of conservation agriculture

Turi Fileccia
Senior Agronomist, Investment Centre Division, FAO

Maurizio Guadagni
Senior Rural Development Specialist, World Bank

Vasyl Hovhera
Economist, Investment Centre Division, FAO

with contributions from:

Martial Bernoux
Soil Scientist, Institut de Recherche pour le Développement (IRD)

DIRECTIONS IN INVESTMENT
prepared under the FAO/World Bank Cooperative Programme

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
Rome, 2014

1818 H Street NW
Washington DC 20433
Telephone: 202-473-1000
Internet: www.worldbank.org

TABLE OF CONTENTS

Foreword		v
Acknowledgements		vi
Acronyms and abbreviations		viii
Executive summary		ix
1	The resource base	1
	Soils	1
2	Crop production	3
3	Soil erosion in Ukraine	5
4	Climate change uncertainties over Ukraine's breadbasket role	7
5	Soil fertility and climate change resistance	10
6	Approaches to address soil erosion	12
7	CA feasibility in Ukraine	14
	CA experiments in Ukraine	14
8	CA adoption in Ukraine	16
9	Potential benefits from CA adoption	18
	Specific advantages for Ukraine	18
10	Soil carbon sequestration	21
	Phasing CA adoption	22
11	Benefits and economics of CA	23
	Farm/enterprise level	23
	National level	24
	Global level	25
12	Next steps	27
	Verification of preliminary estimates	27
	Land markets	27
	Agricultural technology/advisory services	27
	Financial services	27
	Risk management	27
	Food security	27
Annex 1	Ukrainian soils	29
Annex 2	Erosion of Ukrainian soils	36
Annex 3	Land, cropping structure, and yields	40
Annex 4	Climate change in Ukraine	47
Annex 5	Resource-saving technologies in Ukraine	59
Annex 6	Carbon sequestration and climate change mitigation	64
Annex 7	Financial and economic analysis	71
Annex 8	Institutional settings	77

FOREWORD

The findings of this preliminary assessment are the result of field visits to Ukraine in March to June 2013 and interaction with relevant institutional interlocutors, national and international scientists (see Acknowledgments and Annex 8), the donor community, farm managers and owners, agriculture machinery suppliers, technicians and practitioners. A wealth of up-to-date information and data, including important unpublished works, has been collected and analyzed.

This preliminary assessment provides an order of magnitude of the impacts and potential benefits of soil fertility and requires more specific analyses and validations.

This report was prepared prior to the referendum held in the Autonomous Republic of Crimea and the City of Sevastopol on 16 March 2014, and covers the entire territory of Ukraine; in preparing this report the World Bank and FAO do not intend to make any judgment as to the legal or other status of any disputed territories or prejudice the final determination of the parties' claims.

ACKNOWLEDGEMENTS

This report was prepared by a team of specialists of the World Bank and the Food and Agriculture Organization of the United Nations (FAO). The team was coordinated by Maurizio Guadagni, World Bank Senior Rural Development Specialist (ECSAR), and was led by Turi Fileccia, Senior Agronomist, Investment Centre Division, FAO. The team included Vasyl Hovhera, Economist, Investment Centre Division, FAO; Martial Bernoux, Soil Scientist, Institut de Recherche pour le Développement (IRD); Dmitry Prikhodko, Economist, Investment Centre Division, FAO; Stefania Manzo, Agriculturalist, Investment Centre Division, FAO; Rostyslav Lytvyn, PhD candidate in Economics; Rodion Rybchynski, Statistics Analyst; Ana Elisa Bucher, World Bank Climate Change Specialist; and Sandra Corsi, Soil Scientist.

The report was reviewed in FAO by Claudio Gregorio, Service Chief, Europe, Central Asia, Near East, North Africa, Latin America and Caribbean Service; Roble Sabrie, Economist; Bjorn Conrad, Climate Change Officer; and Benjamin O'Brien, Agricultural Officer, all in the Investment Centre Division, FAO. It also benefited from the comments of Amir Kassam, AGPC; Theo Friedrich, FAO Representative in Cuba; and Louis Bockel, ESAS. In the World Bank, the report was reviewed by Erika Jorgensen, Economic Adviser, PREM, ECA; Ademola Braimoh, Senior Natural Resources Management Specialist, AES; and Erick Fernandez, Adviser, Agriculture and Rural Development, LAC.

The team would like to thank the following people for their contribution. Officials: Oleksandr Sen, Deputy Minister Chief of Staff, Ministry of Agrarian Policy and Food of Ukraine (MAPFU); Oleksandr Gordienko, Director, Department of Engineering and Technical Support and Agricultural Engineering, MAPFU: Valery Adamchuk, Director, Institute of Mechanization and Electrification, National Academy of Agrarian Sciences of Ukraine (NAASU); Tetyana Adamenko, Head, Agrometeorology Department, Ukrainian Hydrometerological Centre; Anatolii Balaiev, Chief of Department of Soil Sciences and Soil Conservation, National University of Life and Environmental Sciences of Ukraine; Sviatoslav Baluk, Director, Institute for Soil Science and Agro-chemistry Research, NAASU; Oleksandr Dotsenko, PhD, Institute for Soil Science and Agro-chemistry Research; Nikolai Kosolap, Agronomist, National University of Life and Environmental Sciences of Ukraine; Volodymyr Kravchuk, Director, Ukrainian Research Institute of Forecasting and Testing of Equipment and Technologies for Agricultural Production; Oleksy Krotinov, Agronomist, National University of Life and Environmental Sciences of Ukraine; Oleksandr Kruglov, PhD, Institute for Soil Science and Agro-chemistry Research; Arkadiy Levin, Expert, Institute for Soil Science and Agro-chemistry Research; Anatoly Malienko, Head of Department of Tillage and Weed Control, NSC "Institute of Agriculture of NAASU"; Denys Nizalov, PhD, Economist, Kyiv School of Economics; Nikolai Pavlyshyn, Kyiv Polytechnic Institute; Dmytro Timchenko, PhD, Institute for Soil Science and Agro-chemistry Research; Oksana Tonkha, Soil Expert, National University of Life and Environmental Sciences of Ukraine; Roman Truskavetsky, Professor, Institute for Soil Science and Agro-chemistry Research; Victor Zuza, Head of Research Station, Institute for

Soil Science and Agro-chemistry Research. From the private sector: Arnaud de La Salle, agricultural enterprise "AGRO KMR Ltd"; Olha Dudkina, Senior Agronomist, Agro-Soyuz Holding Company; Volodymyr Khorishko, Co-Owner and Co-Director, Agro-Soyuz Holding Company; Alex Lissitsa, President, Ukrainian Agribusiness Club; Volodymyr Lubomskyj, Director, agricultural enterprise "Agrarne"; Neonila Martyniuk, Responsible for International Development, Agro-Soyuz Holding Company; Sergey Prokayev, Co-Owner, Chief Executive Director, Agro-Soyuz Holding Company; Alan Renard, agricultural enterprise "AGRO KMR Ltd"; Edward Romankov, Executive Director, Agro-Soyuz Holding Company; Ihor Shabliko, Director, agricultural enterprises "Wind" and "Zoria"; Ihor Snehur, Development Officer, Agro-Soyuz Holding Company; and Andriy Vorobyov, Director, Great Plains Ukraine.

ACRONYMS AND ABBREVIATIONS

AEZ	agro-ecologic zones
ABP	agribusiness partnership
CA	conservation agriculture
CEC	cation exchange capacity
CGIAR	Consultative Group on International Agricultural Research
CIMMYT	International Maize and Wheat Improvement Center
EEA	European Environment Agency
EXW	ex-works (the seller's premises)
FAO	Food and Agriculture Organization of the United Nations
FSRP	Food Systems Restructuring Program
FSU	Former Soviet Union
GCM	General Circulation Models
GDP	gross domestic product
GEF	Global Environmental Facility
GFDL	Geophysics Fluid Dynamics Laboratory
GHG	greenhouse gases
GISS	Goddard Institute for Space Studies
IPPC	Intergovernmental Panel on Climate Change
IRR	internal rate of return
MAPFU	Ministry of Agrarian Policy and Food of Ukraine
NAAS	National Academy of Agrarian Sciences of Ukraine
NPV	net present value
NULES	National University of Life and Environmental Sciences of Ukraine
RHH	rural households
SAT	single agricultural tax
SCLR	State Committee of Land Resources
SOM	soil organic matter
SSAI	Soil Sciences and Agro-chemistry (research) Institute
UHMC	Ukrainian Hydrometeorological Centre
UNFCCC	UN Framework Convention on Climate Change
USDA	United States Department of Agriculture
WRB	World Reference Base

EXECUTIVE SUMMARY

Highly favourable agro-ecological conditions and an advantageous geographical location give Ukrainian agriculture its competitive edge

Ukraine is renowned as the breadbasket of Europe thanks to its black soils ("Chernozem" black because of the high organic matter content) which offer exceptional agronomic conditions. One-third of the worldwide stock of the fertile black soils, which cover more than half of Ukraine's arable land, a large variety of climatic zones, and favourable temperature and moisture regimes, offers attractive conditions for the production of a large range of crops including cereals and oilseeds. Ukraine's proximity to large and growing neighbouring markets – the Russian Federation and the European Union – and access to deep sea ports at the Black Sea, provide direct access to world markets, especially large grain importers in the Middle East and North Africa.

Erosion triggered by land tillage is threatening both comparative advantages and competitiveness of Ukrainian crop production systems

Over the years, the Chernozem soils have been widely degraded by poor land management and the resulting soil erosion. It is estimated that more than 500 million tonnes of soil are eroded annually from arable land in Ukraine[1] resulting in loss of soil fertility across 32.5 million hectares and equivalent to around USD 5 billion in nutrient equivalent. This represents a significant loss of the country's main agricultural productive asset: its soils. The value of eroded soil each year is around one-third of the agricultural gross domestic product (GDP). This means that for each dollar of added agricultural value generated, one-third is lost through erosion; or ten tonnes of soil are eroded for each tonne of grain produced[2].

Soil erosion is the major challenge that threatens the comparative advantage of crop production systems of Ukraine. Other major natural damage caused by soil erosion is likely to include siltation of rivers, harbours, and dam reservoirs (feeding hydroelectric power stations).While the above estimates are national averages, the problem is much more acute in specific areas, particularly in the south-east of the country where soil has been eroded to a desertification extent.

There is evidence to suggest that the intensity of erosion and resulting loss of soil fertility is accelerating. Loss in soil fertility inevitably increases production costs of field corps by requiring additional resources to maintain the same productivity (for instance, additional fertilizers to keep the same yield).

1 Source: Official statistic of the Ministry of Agriculture. This assessment is based on two field surveys carried out in 1961 and 1985 in state land of Ukraine (at that time a Soviet Republic). In 2006, Dr. Bulygin made an estimate of 760 million tonnes based on a hydromechanical soil erosion model built on average weighted values for runoff length, slope, soil erodibility, and crop management. The more conservative amount of 500 million has been selected as a cautionary measure.

2 Team estimates based on 500 million tonnes annual erosion versus an average cereals and oilseeds production of 49.8 million tonnes (2006-12 average, source FAOSTAT).

Soil degradation processes driven by erosion imply a number of interlinked issues. Organic matter works like glue that keeps soil particles together, improving their structure. Thus organic matter increases the resistance of soil to mechanical disturbance, such as those produced by rain falling on the ground or a tractor wheel. That is why fertile soils with higher organic matter content are less prone to erosion or compaction, and have higher infiltration. Organic matter also increases soil capacity to hold water. Loss of organic matter reduces its capacity to retain moisture, which is always essential especially during dry years.

During the last 15 years, drought events have increased both in intensity and frequency in Ukraine due to a changing climate. Droughts are now occurring on average once every three years, causing crop productivity decline. It is expected that climate change, and the projected increase of extreme events, will exacerbate these phenomena in the near future. In some major productive areas of the country (the so-called Steppe area, in the southern part of the country) these impacts are more severe than elsewhere. This region produces 50 percent of the grain of Ukraine.

Paradoxically, the high agricultural quality of Ukrainian soils and the prevailing perception of their inherent productivity resilience is delaying much needed remedial measures that should be put in place to first stop and then reverse soil degradation. Without action, the cost to reverse soil degradation is increasing rapidly and in some areas soils have become so degraded that it is now extremely expensive to recover them.

Excessive land tillage is well known to be the major driver of soil erosion. The Ministry of Agrarian Policy and Food of Ukraine (MAPFU) is fully aware of this and is prioritizing erosion prevention and the use of resource-saving technologies. Ukrainian soil scientists and academics - albeit with limited resources and means - are focusing their research on stopping and reversing soil erosion, including the projected negative impacts of climate change. Farmers are under pressure to reduce their production costs to be competitive in the global market and so have begun introducing resource-saving strategies and innovative soil conservation technologies such as minimum tillage.

The considerable expansion of the use of minimum tillage during the last decade (see Table 28) is testimony of the effort towards change. This is a move in the right direction that has already provided a number of important benefits. However minimum tillage technology alone provides only a partial remedy to soil erosion and the loss in soil fertility. Conservation agriculture (CA) with no-till is a more sustainable and effective Climate Smart Agriculture practice which reduces soil erosion, maintains soil fertility, and enhances drought resilience[3] and significantly reduces production costs by minimizing fuel consumption[4].

CA has now been successfully implemented in Kazakhstan, where, with support of the World Bank, the Food and Agriculture Organization of the United Nations (FAO) and the International Maize and Wheat Improvement Center (CIMMYT, 1 of 15 international agricultural research centres part of the Consultative Group on International Agricultural Research [CGIAR] Consortium), the technology has been gradually adopted and reached 1.85 million ha in 2012, contributing to significant productivity and environmental benefits[5].

3 See section "Soil fertility and climate change resilience".

4 See Annex 7.

5 See http://www.eastagri.org/publications/pub_docs/Info%20note_Print.pdf and http://www.worldbank.org/en/results/2013/08/08/no-till-climate-smart-agriculture-solution-for-kazakhstan.

During the last ten years or so, some progressive farmers of Ukraine -- with international exposure -- have also satisfactorily adopted conservation agriculture on about 2 percent of the arable land of the country, mainly in the Steppe area. Unfortunately, this is still happening too sparsely to stimulate wide emulation.

Misconceptions regarding CA technology adaptation, such as the belief that Ukrainian soils are not suitable to the technology, are creating obstacles to widespread adoption. Improved research networking is required to facilitate knowledge sharing on appropriate application and technology effectiveness.

However, the wave of change and the genuine professional interest of agriculture enterprises appear to be increasing. This ought to be further encouraged and leveraged. Should dedicated resources and specific development initiatives be made available, it is likely that agricultural enterprises - beginning with the Steppe area where the erosion issues are more pressing - will start championing a virtuous cycle towards large-scale adoption.

FAO, with World Bank support, carried out a first analytical attempt to quantify the benefits that large scale CA adoption could generate in Ukraine. The country-specific preliminary assessment provides remarkable estimates on the potential benefits at different levels: farm, national and global. The national annual benefits potentially accruing from CA/no-till adoption on 17 million hectares could reach an impressive USD 4.4 billion, or 34 percent of agricultural GDP, and almost stop the USD 5 billion natural capital depletion caused by soil erosion (without counting global environmental and food security benefits). The potential benefits of three scenarios are summarized in the Table 1.

Table 1: Ukraine: Potential impact from the adoption of conservation agriculture

Level	Type	Per 1 ha	Benefits for 3 million ha (short-term)	Benefits for 9 million ha (medium-term)	Benefits for 17 million ha (long-term)
Annual farm benefits	Incremental net income	USD 136	USD 0.41 billion	USD 1.23 billion	USD 2.31 billion
Annual national benefits	Off-farm additional output value and additional soil fertility value	USD 123	USD 0.37 billion	USD 1.11 billion	USD 2.10 billion
Total national benefits		**USD 259**	**USD 0.8 billion**	**USD 2.3 billion**	**USD 4.4 billion**
% share of agricultural GDP			**6**	**18**	**34**
Annual global benefits	Improved food security (additional people fed during drought years, non-monetary benefit)	2.4 people	5.4 million people	16.1 million people	30.4 million people
	Reduced emission	0.5 tonnes CO_2 per year	1.5 million (equivalent to the emissions of 0.3 million cars)	4.4 million (equivalent to the emissions of 0.9 million cars)	8.3 million (equivalent to the emission of 1.7 million cars)
Total investment requirements	Investments in farm equipment and herbicides, plus research and extension	USD 200	USD 0.6 billion	USD 1.8 billion	USD 3.4 billion

The above table represents a rough estimate of the benefits which could accrue from large-scale CA adoption in Ukraine. These estimates, which include the benefits of the area already under CA, were based on the following assumptions:

- The potential areas were estimated on the basis of specific technical and organizational feasibility, soil and crop types. CA would have the maximum potential in the short-term (a few years) to cover an area of about 3 million hectares in the Steppe region (farms of 4 000 hectares and above). The Steppe region has the potential in the medium-term (six to ten years) of reaching 9 million hectares (the entire suitable area in the Steppe region). Ultimately, a gradual move into the Forest Steppe area could be foreseen so that, in the longer term, a total area of 17 million hectares could be converted to CA. The estimates were obtained by multiplying the benefits per hectare for the potential adoption area.
- The incremental net income at farm level is a function of reduced costs for fuel and mechanization, increased long-term yields (after decreasing yields during the first years of technology adoption), higher investment costs for new equipment but lower equipment depreciation, increased costs for herbicides and fertilizers over the first years of technology adoption.
- The off-farm national benefits are estimated as a function of the additional national benefits derived from the following assumptions: (i) the reduction of crop production variability with the introduction of CA/no-till would benefit traders and intermediaries (additional production for the price difference between export and farm gate prices); and (ii) 75 percent soil erosion reduction[6] quantified in terms of the value of NPK nutrients loss avoided. The off-farm benefit from reduced siltation of fluvial infrastructure and reduced import of fuel were not included in these national benefits.
- According to World Development Indicators, the 2008-12 average agricultural GDP of Ukraine is 11.8 billion at current prices.
- Improved food security was estimated in terms of increased supply of cereals on the basis of an average annual consumption of 130 kg of cereals/per capita/per year.
- Carbon sequestration has been estimated on the basis of the global estimates of soil carbon sequestration rates[7] by the Intergovernmental Panel on Climate Change (IPCC) in 2007, see Annex 6.

While climatic conditions are generally favourable in Ukraine, climatic variability, which is expected to increase with climate change, is a considerable risk for agriculture

The volatility of agricultural production is caused by high dependency on natural precipitation since only 2 percent of cropland is irrigated. Although several climatic models predict that a warmer climate would be beneficial overall for agriculture in Ukraine, geographic distribution of benefits is unlikely to be uniform. Increasing temperatures may have some positive impact in the colder and more humid regions in the north of Ukraine. However, in the south of the country, where most fertile chernozem soils are concentrated and where water availability is a limiting factor, increasing temperatures and increasing variability in rain are expected to increase the frequency of droughts and have a negative impact on agriculture.

Soil erosion exacerbates the impact of climatic variability, while simultaneously extreme weather will increase soil erosion. This double link is expected to impose

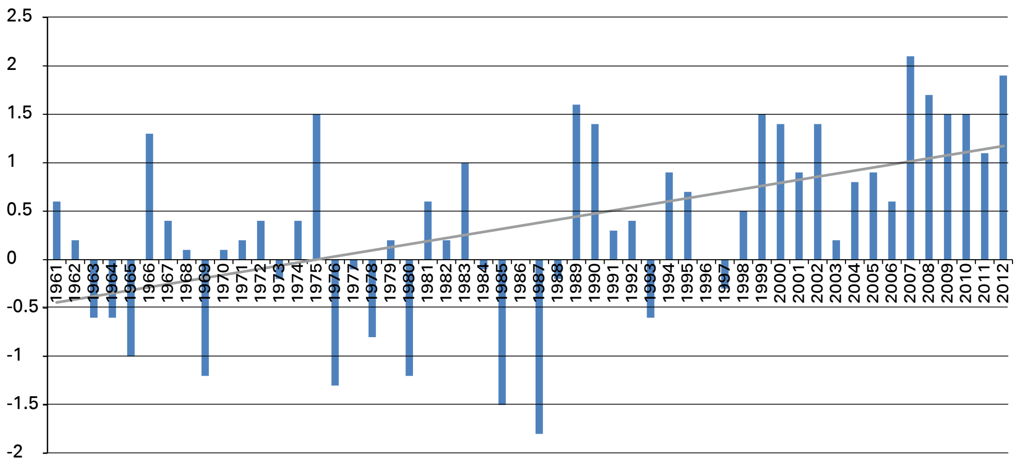
6 This value was selected on the basis of international experience.

7 Annual mitigation of 0.33 tCO_2-eq /ha /yr (this is the average of 0.15 tCO_2-eq/ha/yr-1 for the Cool Dry zone and 0.51 tCO_2-eq /ha /yr-1 for the Cool Moist zone) for soil sequestration + 0.16 t CO_2/ha/year of avoided emission from fuel burning.

a further threat to Ukraine's extraordinary soil fertility and its inherent resilience to climate change. Climate change is expected to lead to increasing frequency, intensity, coverage, duration, and timing of extreme weather and climatic events (IPCC 2012). Extreme climatic events, such as alternating droughts and intense rainfalls, are expected to have a negative impact on agriculture, including but not limited to increased soil erosion. Fertile soils, with abundant organic matter, are more resilient to wind and water erosion than unstructured soils, with low organic matter. Intense rainfalls increase water erosion, while dry soils are more susceptible to wind erosion.

Agricultural productivity depends on natural precipitation and temperatures which are affected by significant inter-annual and seasonal variability. It is expected that climate change will further exacerbate the already high volatility of agricultural production and negatively affect food security. High production variability in Ukraine may have implications for global trade and world price volatility. The 2009 drought and consequent loss of almost 30 percent of Ukraine's wheat crop was an important trigger in the global food price rise.

Figure 1: The climate of Ukraine is changing, 1961-2012
Average annual air temperature deviation from the norm



Source: World Bank Climate Change Knowledge Portal.

Most future climate predictions are based on General Circulation Models (GCM) which predict an overall increase in precipitation in the region. However, there are conflicting estimates on the potential impact of these changes on agriculture. The difference in the estimates highlights the lack of robust climate analysis in terms of seasonal variability, timelines, baselines used, and overall assessment of a range of climate models outputs and associated uncertainties for the interpretation of predicted impacts. It is therefore important to recognize the inherent uncertainties of each model in its ability to predict a changing climate. Additional modelling studies[8] indicate that although large portions of Ukraine might increase their agricultural potential under warming scenarios, agriculture in the semi-arid southern zone could suffer a dramatic increase in frequency of droughts.

Any projection of agricultural expansion based on climate change scenarios should be viewed with caution, if they do not take into account other regional socio-economic

8 Alcamo *et al.* (2007) and Dronin and Kirilenko (2008).

factors such as land degradation, access to improved seeds, etc.[9] Expansion of climatic zones suitable for agriculture does not necessarily imply that the local population currently employed in other sectors would seek out new opportunities in agriculture, or will be prepared to change agriculture practices such as use of market-preferred improved seeds varieties. On the other hand, declining productivity due to increasing aridity in the southern area of Ukraine may result in the loss of human capital as skilled farmers may be forced to switch to other activities. Assessment of human vulnerability and adaptation to climate change needs to become a key component of agricultural policies. Adaptation, such as large-scale implementation of soil-water conservation measures (i.e. no till), introduction of drought resistant crop varieties and development of irrigation are crucial to increase climate resilience and food security.

Suggested steps to address these concerns

Several of the next steps proposed below require additional financing. With regard to the global benefits that the proposed actions could generate, there are some sources of international financing for which Ukraine could apply. For instance, grant funding from the Global Environmental Facility (GEF) and from the Adaptation Fund is available for Ukraine. The GEF will start a new funding period in July 2014 (called GEF-6), where funds are available for Ukraine to address issues related to climate change (USD 17.4 million) and land degradation (USD 2.9 million). The GEF does require co-financing, usually at least four times that of the GEF grant amount. The Adaptation Fund has a grant of up to USD 10 million available for Ukraine. The Adaptation Fund has financed agricultural adaptation investments in many countries, in line with the actions suggested above. The suggested next steps are as follows:

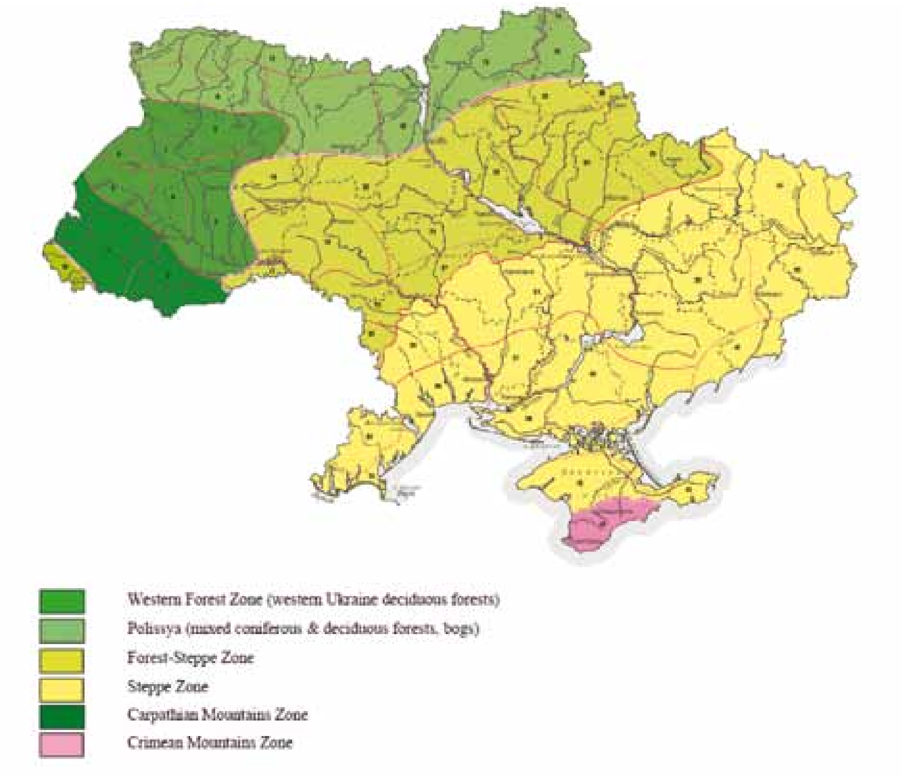
(i) Verification of preliminary estimates: This preliminary assessment would benefit from a more detailed follow-up investigation to address areas such as detailed on-farm productivity; economic and environmental analyses for technology comparison; assessment of agricultural machinery capacity and market; evaluation of erosion impact on river systems and siltation.
(ii) Land markets: Increase confidence in long-term use of land so as to create incentive for farmers who use arable land to invest in soil fertility.
(iii) Agricultural technology/advisory services: Develop a programme of agricultural technology/advisory services to address soil fertility concerns.
(iv) Financial services: Consider developing a programme to facilitate access to finance for those farmers who invest in environmentally friendly approaches such as Conservation Agriculture. Work with agricultural insurance so that CA does not pay higher premiums.
(v) Risk management: Work with the research and farm community to improve the quality of climate change estimated potential impact on agriculture, differentiating risks and adaptation approaches by agro-ecological region.
(vi) Food security: Strengthen incentives for adopting technologies to maintain soil fertility and reduce the volatility of agricultural production, such as CA with no-till.

The potential benefits presented in this study (Table 1) and the risks caused by a changing climate should constitute a strong incentive to increase soil fertility efforts and strengthen climate resilience.

9 Lioubimtseva, 2010.

1. The resource base

Figure 2: Agro-ecologic zones (AEZ) of Ukraine



Source: MAPFU "On state of soil fertility in Ukraine", Kyiv 2010.

Ukraine is the second largest country in Europe (603 700 km^2) with three large agro-ecological zones and two mountain regions: a Forest zone (Polissya) in the North (19 percent of total land); a Forest-Steppe zone (35 percent) to the South; a Steppe zone in the South and South-East (40 percent); and the Carpathian and Crimean mountains, which occupy respectively the west and the very southern part of the country.

The Steppe zone covers 19 million hectares of agricultural lands; the Forest-Steppe zone 16.9 million hectares, and the Forest zone 5.6 million hectares.

Soils[10]

Ukraine has some of the most fertile soils in the world, including the famous Chernozems, deep black soils rich in humus. Chernozems occupy about half of the country (about 68 percent of the arable land), followed by Phaeozems and Albeluvisols.

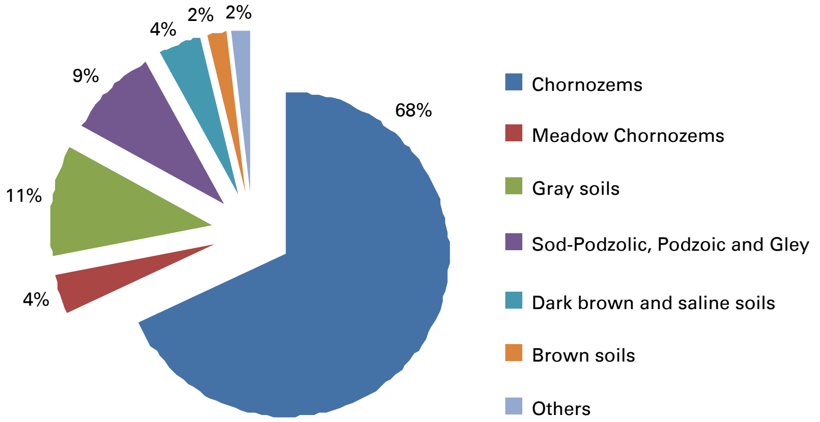
Physical, chemical and biological nominal data of Ukrainian soils and their classification were studied in the late 1950s (completed in 1961). Since then no countrywide soil data update has been done[11].

Nominal soil organic matter (SOM) content of chernozems ranges from 5.2 percent in wet

10 For further details see Annex 1.

11 Sviatoslav Baluk, Director, Institute for Soil Science and Agro-chemistry Research during roundtable discussions in Kyiv, 23 May, 2013. See also note n. 11.

Figure 3: Soils of Ukraine



Source: team elaboration from Balyuk S.A, 2013.

Table 2: Ukraine: agropotential of chernozem soil for winter wheat

Zone	Soil	Yield agro potential		Percentage of arable land
		Natural (q/ha)	Optimal (q/ha)	%
Forest Steppe	Chernozem podzolic	30 - 38	40 - 48	8.6
	Chernozem Typical	32 - 36	38 - 45	14.5
	Typical chernozem and Meadow	30 - 36	54 - 64	1.0
Steppe	Chernozem ordinary	23 - 34	31 - 40	26.3
	Chernozem Southern	18 - 25	22 - 31	9.1

Source: team elaboration from Balyuk, 2013.

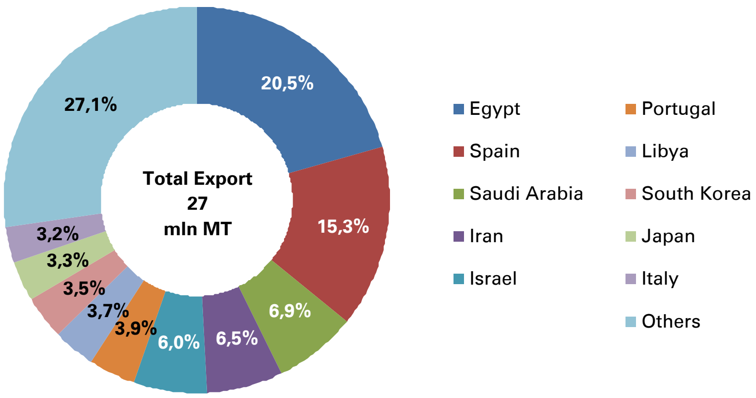
Forest-Steppe to 5.7 percent in Forest-Steppe, and 6.2 percent in Steppe, to 3.4 percent or less in South Steppe. Fertility follows a similar pattern, decreasing from Forest Steppe to southern Steppe.

This behaviour is partly dependent on the Cation Exchange Capacity (CEC)[12] of the soils. Soil organic materials increase the CEC and so organic matter build-up impacts positively on soil fertility and productivity. The physical properties of the Chernozems are also crucial for their agronomic potential.

12 CEC is the maximum quantity of total cations available for exchange with the soil solution that a determined soil is capable of holding. CEC correlates with the soil fertility and is definitely dependent on the mineral matrix but also on the amount and quality of soil organic matter.

2. Crop production[13]

Figure 4: Destination of Ukraine cereals exports, 2012



Source: State Customs Committee of Ukraine, Global Trade Atlas.

Table 3: Agricultural lands by ownership in 2012

	Operators			Total
	Enterprises	Rural Households	Others	
Units	47 652	5 100 000		
Agricultural land, million ha	20.7	15.8	5.0	41.5
Arable land, million ha	19.4	11.6	1.5	32.5

Source: MAFP, Panorama of Ukraine Agrarian Sector 2012.

During 2008-2012, Ukraine ranked sixth and third largest world wheat and coarse grains[14] exporter, respectively. The country exported about 23 million tonnes of cereals. The total value of cereals exports reached almost USD 7 billion mostly to North Africa, the Middle East and Europe, as shown in Figure 4.

Sixty-nine percent of Ukrainian territory is agricultural land, totalling 41.5 million ha of which 32.5 million ha is arable land. Eighty eight percent (36.5 million ha) of total agricultural land is owned by agricultural enterprises (about 48 000 units), and by rural households (RHH)[15].

The total crop area in Ukraine amounts to 27.8 million ha; over 55 percent of crop lands are used for cereal production. Crop land use change since 2000 has been mainly in favour of industrial crops (oilseed); and within the cereal area, in favour of corn.

Ukraine is characterized by volatile wheat and coarse grains productivity. On average, every three years, wheat production changes by 20 percent and corn by 25 percent. This has a major impact on Ukraine's trade balance.

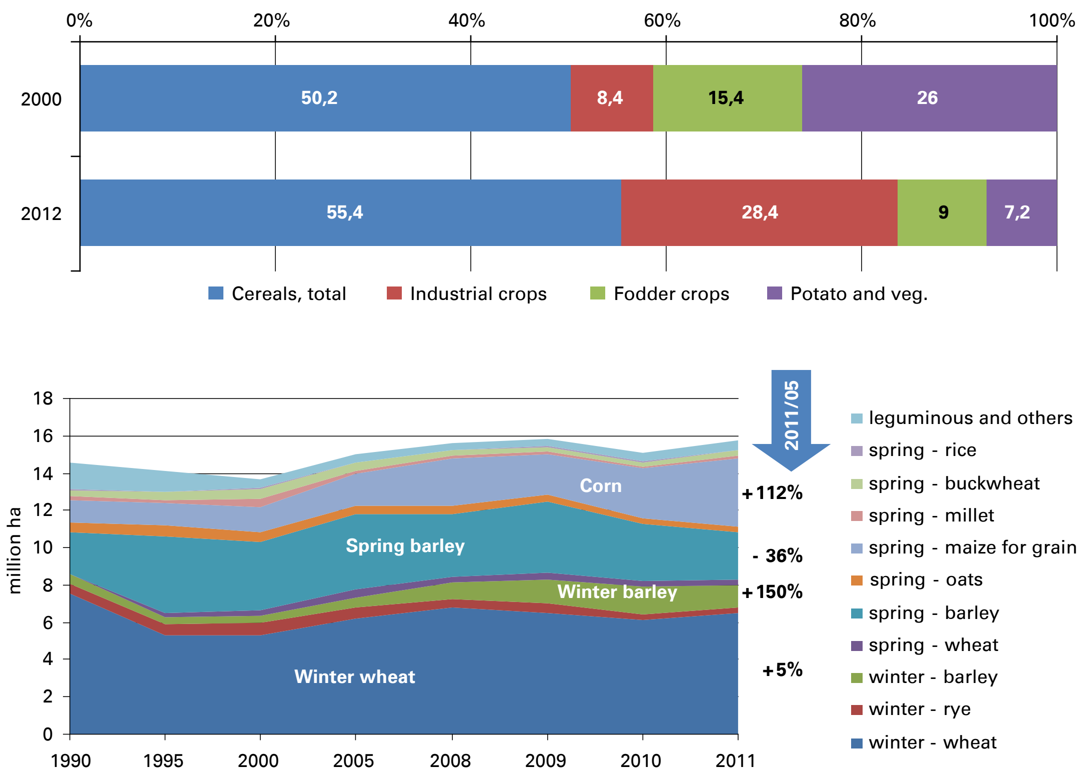
Lower wheat yields volatility is a feature of provinces in the Forest-Steppe and Forest zones, and in Mykolaiv province. On the contrary, the Steppe zone is usually characterized by high volatility especially Kharkivska province. Corn yields are also more volatile in the Steppe zone, particularly in the Luhanska and Kharkivska provinces.

13 For further details see Annex 3.

14 Coarse grains refer to cereal grains other than wheat and rice.

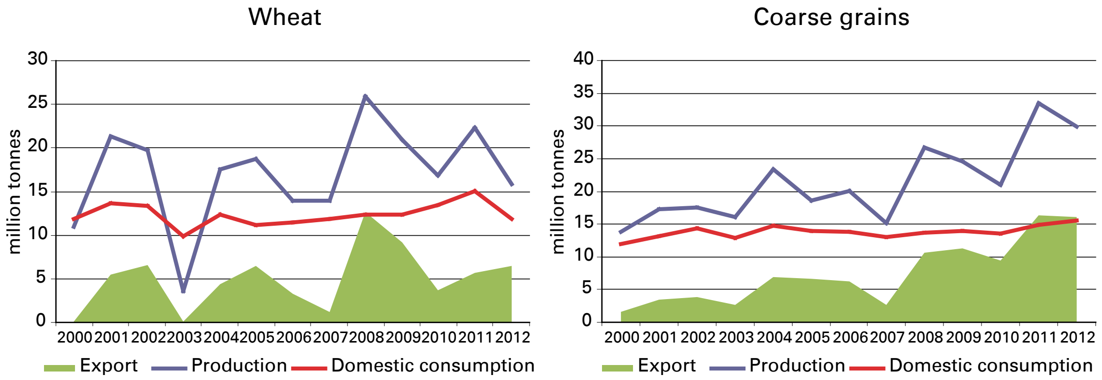
15 Source: Ministry of Agrarian Policy and Food (MAPFU), Panorama of Ukraine Agrarian Sector 2012.

Figure 5: Ukraine: evolution of crop areas

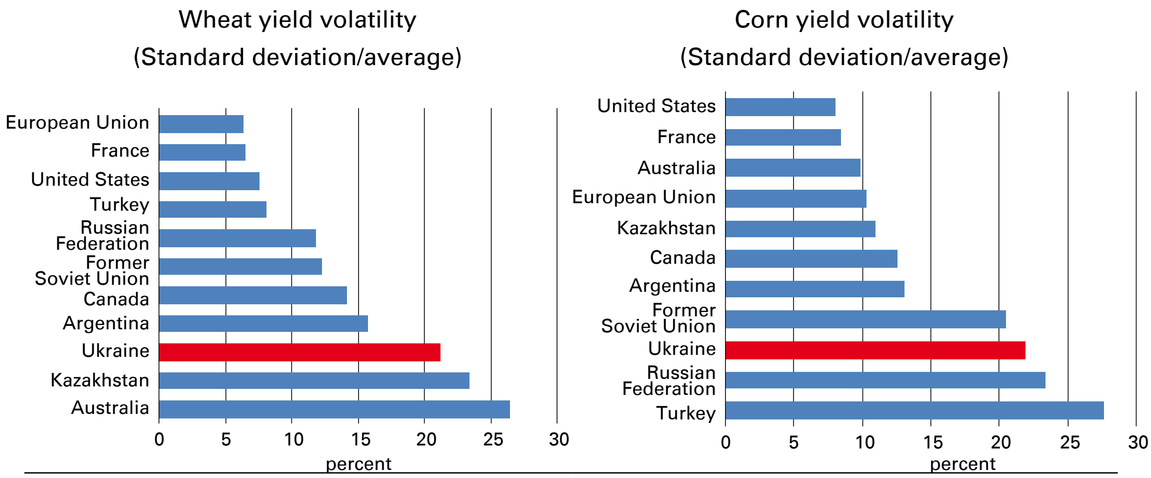


Sources: MAFPU, Panorama of Ukraine Agrarian Sector 2012 and UkrStat.

Figure 6: Production, exports and yield variability, 2000-2012



Source: FAO OECD Agricultural Outlook 2013-22.



Source: Team calculations based on PSD USDA.

3. Soil erosion in Ukraine[16]

At the time of the Soviet Union, agricultural intensity and land tillage were very high in Ukraine, causing significant erosion. According to FAO (Bogovin, 2006), the annual soil losses in the Soviet times amounted to as much as 600 million tonnes, including 20-30 million tonnes of humus. An estimated 40 percent of the country's territory is now eroded at different levels of severity, and an additional 40 percent is prone to further wind and water erosion.

A 1996 study by the State Committee of Land Resources (SCLR) reported that 13.2 million ha were exposed to water erosion, and 1.7 million ha were exposed to wind erosion[17], increasing at a rate of about 60 000-80 000 ha per year. Erosion was estimated in 2013 to affect about 1 414.5 million hectares. This is also confirmed by the Soil Sciences and Agro-chemistry (research) Institute (SSAI O.N. Sokolovsky)[18]. Erosion impact has been exacerbated in the post-Soviet era by significantly reduced application of mineral and organic fertilizers, which has caused a sharp decline in soil humus content.

MAPFU[19] official statistics estimate that about 500 million tonnes of soil are lost annually from 32.5 million ha arable lands. This means that an average of 15 tonnes per year is eroded from arable land. This estimate is credible and in line with erosion in similar conditions. It is based on two field surveys carried out in 1961 and 1985 in state land in Ukraine (at that time a Soviet Republic). In 2006, Dr. Bulygin estimated that 760 million tonnes per year were lost from arable land. This was based on a hydromechanical soil erosion model using average weighted values for runoff length, slope, soil erodibility, and crop management. The more conservative amount of 500 million tonnes has been selected as a more cautious measure.

The amount of soil eroded corresponds to 23.9 million tonnes of humus, 964 thousand tonnes of nitrogen, 676 thousand tonnes of phosphorus and 9.7 million tonnes of potassium. At market price[20], this amount of NPK nutrients corresponds to over USD 5 billion of losses per year (USD 157 per hectare).The yearly loss ranges from about 3 to 30 tonnes of soil per hectare depending on the region. This is estimated to amount to a loss of about USD 5 billion per year (2013). A loss of 10 tonnes of soil corresponds to a loss of 0.5 tonnes of Carbon (C) per ha: a significant amount when compared with the existing potential soil C sequestration levels. There is evidence to suggest that the intensity of erosion is accelerating (Bulygin and Nearing, 1999).

Soil erosion represents a significant loss of the country's main agricultural productive asset: its soils. Such erosion of productive capital is substantial. The value of eroded soil each year is around one-third of the agricultural GDP. This means that for each dollar of agricultural value added generated, one-third is lost through erosion; or ten tonnes of soil are eroded for each tonne of grain produced.

16 See Annex 2 for more detail.

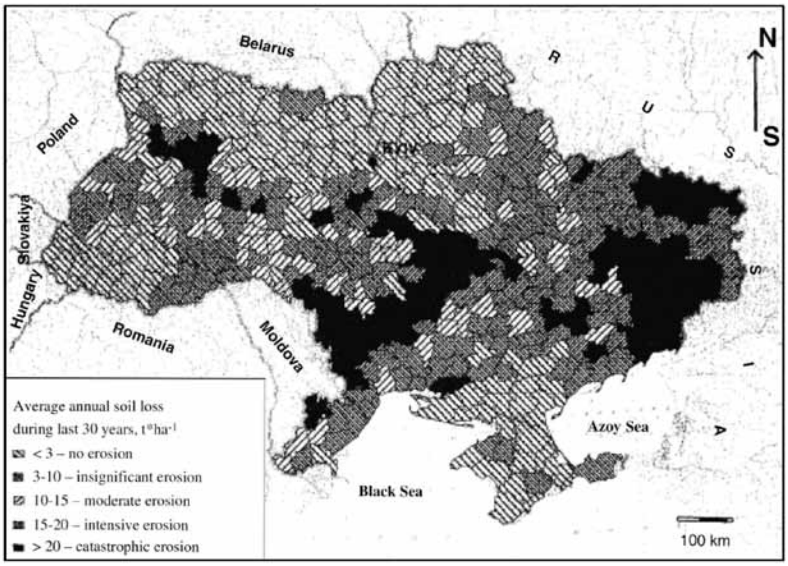
17 World Bank, 2007.Integrating Environment into Agriculture and Forestry Progress and Prospects in Eastern Europe and Central Asia. Volume II. Ukraine, Country Review. 22 pp. www.worldbank.org/eca/environmentintegration.

18 Founded in 1956 and named after academician Oleksiy Nykanorovych Sokolovskyj. The Research Institute is in charge for providing rational exploitation of the land resources, protection and increase of soil fertility. It oversees national and state programmes; analyzing and proposing also normative bases on development of soil science, agro-chemistry and soil protection. The Soil Map of Ukraine was developed by this institute (1957-1961).

19 Reported by Bulygin S., 2006. Ukraine. Pages 199-204.Soil Erosion in Europe (Boarman J and Poesen J. Editors), John Wiley and Sons.

20 The price estimates used to calculate the market value of NPK nutrients are the following: 3300 UAH per 1 Tonne of N, 5750 UAH per tonne of P and 3570 UAH per tonne of K. These are conservative price estimates and do not value the downstream damage.

Figure 7: Average annual soil loss during the last 30 years from Ukrainian arable land



Source: Bulygin, 2006.

4. Climate change uncertainties over Ukraine's breadbasket role[21]

Even though Ukraine is renowned as the breadbasket of Europe, food security does not rank high in international comparisons. The Economist Global Food Security Index ranked Ukraine as 45th in a list of 105 ranked countries. Two factors negatively affect Ukrainian food security: (i) a high share of household expenditure is dedicated to food, and (ii) the volatility of agricultural production is higher than the average of other countries[22].

The volatility of agricultural production is caused by high dependency on natural precipitation since only 2 percent of cropland is irrigated. In turn, natural precipitation is affected by significant inter-annual and seasonal variability. It is expected that climate change and increasing variability will further exacerbate the already high volatility of agricultural production and thus negatively affect food security. Indeed, high production variability in Ukraine may have implications for global trade and world price volatility.

The second major climatic constraint is the temperature: high temperatures increase evapotranspiration (plants' water demand) and heat waves (above 33°C) can damage crops and reduce production. Historical trends show that during the past half century the average temperature of the country has been increasing significantly.

Increasing temperatures may have some positive impact in the colder and more humid regions in the north of Ukraine, where extremely cold temperatures cause winterkill and consequent productivity loss. However, in the south of the country, where water availability is a limiting factor, increasing temperatures and increasing variability in rain events are expected to increase the frequency of droughts and thus have a negative impact on agriculture.

Most future climate predictions are based on GCM, which expect an overall increase in precipitation in the region. However, there are conflicting estimates on the potential impact of these changes on agriculture. For instance, according to a recent Ukrainian study[23] based on the Geophysics Fluid Dynamics Laboratory (GFDL) model, a 30 percent increase of greenhouse gas (GHG) emissions, winter wheat yields are expected to increase by 37 percent by 2030-2040 mainly due to increase in temperature. However this study does not consider other factors such as soil, land management, or crop behaviours. A previous study by the International Institute for Applied Systems Analysis[24] predicted that yields of rainfed high-input cereals in southern Ukraine would decrease by 10 percent by 2050 and by 17 percent by 2080. This second study is based on the different conditions of agro-ecological zones within the country.

The difference in the above estimates highlights the lack of robust climate analysis in terms of seasonal variability, time-lines, baselines used, and overall assessment of a range of climate models outputs and associated uncertainties for the interpretation of predicted impacts. Consequently it is important to understand the inherent uncertainties of each model in their ability to predict a changing climate.

Projections of grain production and export increases are based on assumptions of increasing trends in yields and in increasing arable land suitable for specific crops. However, most grain productivity projections do not take

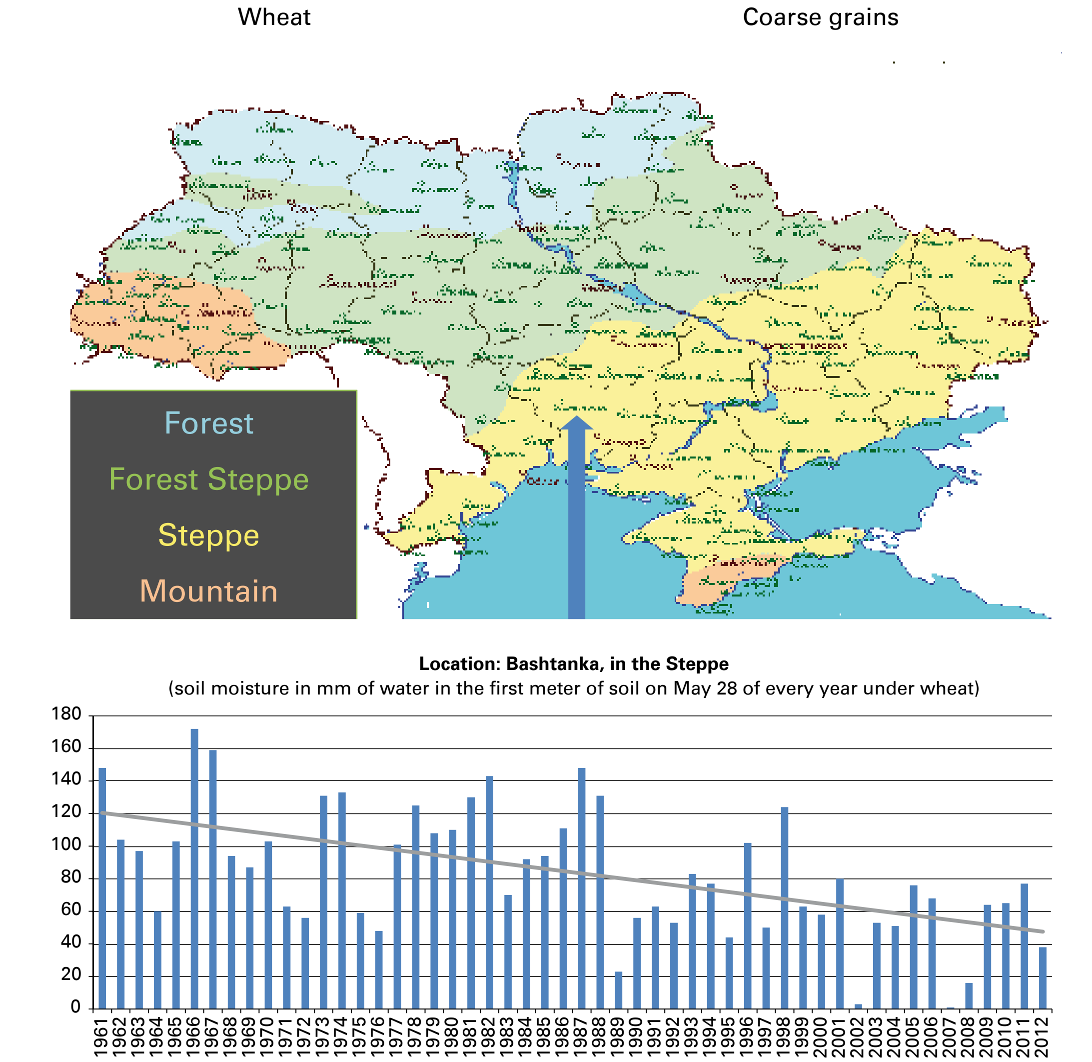
21 For further details see Annex 4.

22 56 percent of total household expenditures are dedicated to food against an average of 39 percent, while standard deviation of agricultural productivity is 0.17 versus 0.1 (http://foodsecurityindex.eiu.com/Country/Details#Ukraine).

23 Ibid, compared with a baseline of 1995-2009 average yields.

24 Fischer, G., F. Nachtergaele, S. Prieler, H.T. van Velthuizen, L. Verelst, D. Wiberg, 2008, compared with the baseline average yields of 1961-1990 based on experiments with four General Circulation Models (GCM), and the assessment of four basic SRES scenarios from IPCC Third Assessment Report.

Figure 8: In southern Ukraine, soil moisture has been halving



Source: Adamenko 2012, presentation on "Agrometeorological monitoring and climate change in Ukraine".

into account changes due to variability in the frequency of extreme events, such as droughts and frosts. The potential changes in variability and extreme events – frosts, heat waves, droughts, and heavy rains – are likely to have a stronger impact on food production than shifts in temperature and precipitation.

Although several climatic models predict that a warmer climate would be beneficial for agriculture in Ukraine[25], geographic distribution of benefits is unlikely to be uniform. This can also be seen by historic trends of reduced soil moisture in the southern part of the country (see Figure 8). If these historical trends continue in the future, as expected by many models, this will create a serious obstacle to agricultural productivity.

Additional modelling studies[26] indicate that although large parts of Ukraine might increase their agricultural potential under warming scenarios, agriculture in the semi-arid southern zone – where most fertile Chernozem soils are concentrated – could suffer a dramatic increase in frequency of droughts.

Finally, any projection of agricultural expansion based on climate change scenarios should be viewed with caution, if they do not take into account other regional socio-economic factors, such as land degradation, access to improved

25 Pegov *et al.*, 2000; Fischer *et al.*, 2002; 2005; Parry *et al.*, 2004).

26 Alcamo *et al.* (2007) and Dronin and Kirilenko (2008).

crops, etc.[27] Expansion of climatic zones suitable for agriculture does not necessarily imply that the local population currently employed in other sectors would seek out new opportunities in agriculture, or will be prepared to change agricultural practices such as use of improved seed varieties. On the other hand, declining productivity due to increasing aridity in the southern area of Ukraine may result in the loss of human capital as skilled farmers may be forced to switch to other livelihoods.

Assessment of human vulnerability and adaptation to climate change needs to become a key component of agricultural policies. Adaptation, such as implementation of large-scale soil-water conservation measures (i.e. no till), introduction of drought resistant crop varieties and development of irrigation are crucial to increase climate resilience and food security.

27 Lioubimtseva, 2010.

5. Soil fertility and climate change resistance

The productivity of a soil depends on its physical, chemical and biological properties and, in particular, on its mineral composition, organic matter content and biological activity. Appropriate levels of SOM ensure soil fertility and minimize agricultural impact on the environment.

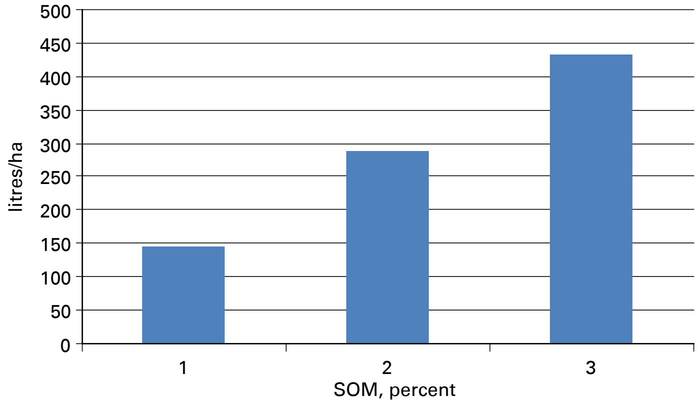
It is estimated that globally some 5-10 million hectares are being lost annually to severe degradation and declining yields (or increased input requirements to compensate). This includes physical degradation by water and wind, crusting, sealing and waterlogging; biological degradation due to organic matter depletion and loss of soil flora and fauna; and chemical degradation by acidification, nutrient depletion, pollution from excessive use of pesticides and fertilizers or human and industrial waste.

The Pan-European Soil Erosion Risk Assessment estimates that almost a quarter of Europe's land is at some risk of erosion. Risk is defined as "high" or "very high" for 10 million hectares of Europe's lands and "moderate" on a further 27 million hectares (European Environment Agency [EEA], 2005). Eroded soils are apt to suffer from supplementary degradation such as reduced efficiency in filtering pollution, in capturing water to sustain crop production or replenish underground water reserves, and in storing atmospheric carbon. The latter can contribute to a further decrease in the already low or very low organic carbon content in many lands in Europe and badly affects soil structure and biodiversity.

The EEA states that despite erosion being a natural phenomenon, several human activities, such as forest clearance and inappropriate farming practices, increase soil loss (EEA, 2005). Unsustainable land management practices, which are degrading soils and are consequently reducing the fertility of the land include: continuous cropping with reductions in fallow and rotations, soil preparation methods based on mouldboard tillage, organic matter removal, overstocking, overgrazing and burning of rangelands, over-exploitation or clearance of wooded and forest lands (Van Muysen and Govers, 2002; Marques da Silva and Alexandre, 2004; Li *et al.*, 2007). These practices are reducing the productive capacities of croplands, rangelands and forests worldwide while inducing farmers to apply more artificial inputs to maintain production (Lobb *et al.*, 1995; Lobb and Lindstrom, 1999; Reicosky *et al.*, 2005).

From an environmental perspective, degraded soils are at greater risk from the damaging

Figure 9: Soil organic matter and water holding capacity



Source: Jones, 2006.

impacts of climate change due to loss of SOM and soil biodiversity, increased soil compaction and increased rates of soil erosion and landslides. Organic matter works like glue keeping soil particles together improving their structure. Thus organic matter increases the resistance of soil to mechanical disturbance, such as those produced by raindrops falling on the ground. That is why fertile soils with high organic matter content are more resistant to heavy rains, less prone to erosion, and have higher infiltration.

Proper soil management can also influence rainwater infiltration and the capacity of the soil to reduce soil water evaporation and store water in the soil profile. Soil protected by a superficial layer of organic matter, as in CA systems, improves the capture and the use of rainfall through increased water absorption and infiltration and decreased evaporation from the soil surface. This leads to reduced runoff and soil erosion and higher soil moisture throughout the season compared with unprotected soils (Kronen, 1994; Duiker and Lal, 2000; Post and Kwon, 2000; Knowles and Singh, 2003; Baker, 2007; Bationo *et al.*, 2007). This is due to three separate processes. First, SOM plays a major role in absorbing water at low moisture potentials. A 1 percent increase of SOM in the top 30 cm of soil can hold 144 000 litres of water, which is available for crop needs (Figure 9). This is why soils rich in organic matter increase crop resilience to droughts.

Second, soil protection through organic matter and the higher presence of large water-stable soil aggregates enhances resistance against water and wind erosion (Puget *et al.*, 1995; Balabane *et al.*, 2005). Third, water infiltration rate is a function of the initial water content and soil porosity. Porosity and its distribution down the profile depend on soil texture and structure, aggregate stability, SOM content and therefore on the type, shape and size of soil structural units; the presence of channels created by roots, mesofauna and macrofauna also play a role. In low clay soils, organic matter is the main stabilizer of soil aggregates and pores; neither silt nor sand have cohesive (i.e. plastic) properties. Therefore, soil management in general, and CA in particular, can influence rainwater infiltration and increase the effectiveness of rainfall, enhancing productivity, reducing rates of erosion, dispersion of soil particles and reducing risks of waterlogging and salinity.

6. Approaches to address soil erosion

Sustainable land management approaches to reduce soil erosion can be classified as land use regimes, agronomic and vegetative measures, and structural measures, as seen in Table 4.

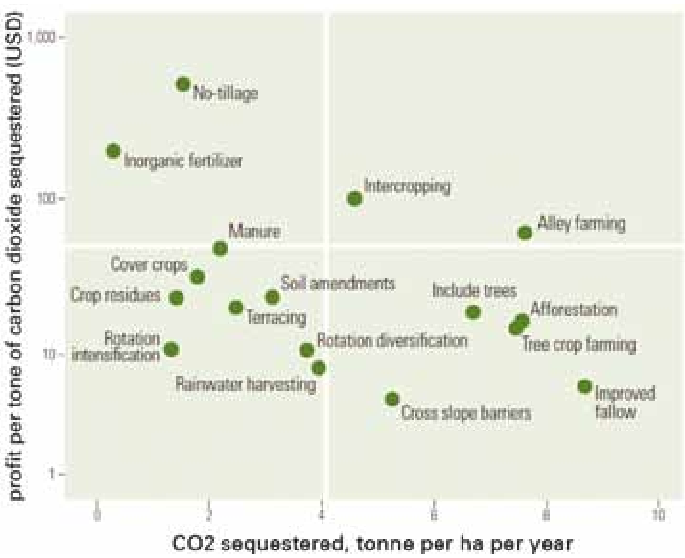
However, no-till stands out in terms of profitability per tonne of carbon dioxide sequestered, as shown in Figure 10 (note the logarithmic scale to measure profitability). The problem with no-till alone is that weed and pest management becomes challenging over time. Therefore, in order to be fully sustainable over time, it needs to be combined together with soil cover and crop rotation. The combination of these three elements is called conservation agriculture by FAO.

Table 4: Sustainable land management approaches

Land use regimes	Agronomic & vegetative measures	Structural measures
• Watershed plans • Community land use plans • Grazing agreements, closures, etc. • Soil and water conservation zones • Vegetation corridors	• Intercropping • Natural regeneration • Agroforestry • Afforestation and reforestation • No tillage • Mulching and crop residue • Crop rotation • Fallowing • Composting/green manure • Integrated pest management • Vegetative strip cover • Contour planting • Re-vegetation of rangelands • Integrated crop-livestock systems • Woodlots • Live fencing • Alternatives to woodfuel • Sand dune stabilization	• Terraces and other physical measures (e.g. soil bunds, stone bunds, bench terraces, etc.) • Flood control and drainage measures (e.g. rock catchment' water harvesting, cut-off drains, vegetative waterways, stone-paved waterways, flood water diversion, etc.) • Water harvesting, runoff management, and small-scale irrigation (shallow wells / boreholes, micro ponds, underground cisterns, percolation pits, ponds, spring development, roof water harvesting, river bed dams, stream diversion weir, farm dam, tie ridges, inter-row water harvesting, half-moon structures, etc.) • Gully control measures (e.g. stone check dams, brushwood check dams, gully cut/reshaping and filling, gully re-vegetation, etc)

Source: World Bank 2012.

Figure 10: Profitability and carbon sequestration of sustainable land management approaches



Source: Carbon Sequestration in Agricultural Soils (World Bank report #67395-GLB).

The FAO definition[28] of conservation agriculture (CA) is:

> *An approach to managing agro-ecosystems for improved and sustained productivity, increased profits and food security while preserving and enhancing the resource base and the environment. CA is characterized by three linked principles, namely:*
>
> - *continuous minimum mechanical soil disturbance;*
> - *permanent organic soil cover; and*
> - *diversification of crop species grown in sequences and/or associations.*

This approach is practised on around 125 million ha globally (9 percent of global arable land), and it is increasing at a rate of around 6 million ha per year. Although this is more than twice the adoption rate of organic farming, public knowledge about CA is much lower than that about organic farming. CA includes a set of farm practices that produce sustainable and synergic benefits when adopted simultaneously and continuously. With this approach, weeds are controlled chemically rather than through cultivation (that is why the cost of herbicides can initially increase). CA still requires other agricultural practices such as fertilization and Integrated Pest Management in a way similar but not identical to traditional ploughing. When the above farm practices are applied continuously, they significantly improve soil fertility and produce more and more sustainable benefits than each individual practice alone. The three principles can be further explained as follows:

- continuous minimum soil disturbance is commonly known as "no-till". This is the practice of sowing without tillage, also called "direct seeding" (the practice of seeding directly into unprepared soil);
- permanent organic soil cover can be achieved using crop residues, mulching, or cover crops. It requires a total stop to burning crop residues, a farm practice which produces soot or black carbon, a little known but increasingly important cause of climate change; and
- diversification of crop species grown in sequences and/or associations crop rotation is achieved with crop rotation and/or intercropping.

CA is distinguished from "minimum tillage", which means reducing to some extent the traditional mouldboard ploughing[29], which includes turning the soil. Minimum-till and no-till are often jointly referred to as "resource-saving technologies". While minimum tillage does present important benefits, long-term international trials and studies have proved that the combination of the above three practices is essential to maximize benefit. For instance:

- no-till with crop residue coverage but no rotation presents the risk that weed and pest control will become unmanageable over time;
- ploughing an area previously under CA does significantly reduce its soil organic matter and therefore it reduces its soil water holding capacity, which is the key element to soil drought resistance; it also determines a reversal of the benefits gained; and
- no-till without crop residues risks causing soil compaction.

Although the above three farm practices are the minimum requirements additional practices can be included to improve soil fertility, such as inclusion of multiannual crops (such as pastures) or windbreaks.

The term "resource-saving technologies" is used in the Former Soviet Union (FSU) to mean without distinction CA, no-till, and minimum till. See Annex 5 for more detail on this.

28 http://www.fao.org/ag/ca/1a.html.

29 British spelling "mouldboard plough".

7. CA feasibility in Ukraine

Ukrainian scientists have concerns about the feasibility of CA/no-till technology in the country. The main concerns include the following:

- soil-related (soils too hard, sandy, stony, over moisturized, gleyish);
- climate-related (cold moist spring delaying nitrification processes and causing nitrogen deficit);
- technical (excess of weeds, rodents, and pests/diseases);
- organizational (need to invest in specialized machinery and related technical assistance, financial constraints and overuse/management of herbicides and agrochemicals).

As discussed with some scientists, these concerns can all be addressed through practical learning on soil- and farm-specific cases. Moreover, it is being acknowledged that while the price of fuel has been increasing in the past few years, the price of commonly used herbicides in CA/no till practices has been decreasing. This is increasing the benefits of CA adoption.

International experience shows that initial hesitation toward this technology is normal. CA adoption is a slow process, usually requiring decades. This is due to several reasons: (i) ploughing is the quintessence of crop cultivation. Abandoning such a basic tradition is culturally challenging; (ii) some benefits – particularly those dealing with soil health improvement and environmental services – materialize increasingly as time goes on, whereas others such as improvements in profit, savings on production inputs, reduction in erosion and other forms of soil degradation can be harnessed from the beginning; (iii) farm management and weed control require a significant shift in approach to how crop establishment and weed management operations are implemented. Farmers can do much to innovate during the uptake and adoption process so that locally adapted practices are utilized to implement CA principles. When CA is a new concept and there is little local experience to draw from, farmers will need to learn about CA practices and adapt them to suit their conditions. Adoption of CA practices occurs gradually as farmers become more familiar with both the theory and the practice of CA methods. This can be done by slowly reducing mechanical soil disturbance, going in the direction of minimum tillage, and/or by incrementally developing the three practices of Conservation Agriculture, beginning with a small part of the farm.

Without a specific and organized public sector support, this technological change may take a long time or it can be accelerated with enabling support. That is why several European regions are moving in the direction of providing specific subsidies for CA adoption. For the same reason the United States Department of Agriculture (USDA) includes (with a rigorous protocol) the no-till practice in the Farm Bill.

CA experiments in Ukraine

Trials[30] carried out on yield comparisons show controversial results when comparing traditional, minimum- and no-till technologies. Admittedly, it is recognized that in these trials the no-till technology is applied improperly. In fact, depending on which crop is included in the rotation even the no-till field is ploughed on that occasion. This single operation cancels all the gains the technology was re-establishing on that given soil.

In terms of soil humus content - which has been computed while comparing the three technologies on soils which had a high SOM starting point (above 4 percent) – gains were marginal but evident at the first ten (0-10 cm) and first twenty

30 Presentation made by Professor S.A. Balyuk during round-table discussions in Kyiv on 23 May, 2013.

Table 5: Ukraine: chlorophyll content in winter wheat leaves

Traditional ploughing	Mini-till	No-till
In standard units with N-tester		
48.5	50.1	52.8

Source: SSAcI O.N. Sokolovsky (Kharkiv, May, 2013).

(0-20 cm) centimetres of the soil. Otherwise at 10-20 cm and at 20-30 cm, very slight decreases (0.02 percent and 0.14 percent) were recorded. An interesting trial, which is being conducted by SSAI, on the chlorophyll content of crop leaves for the three technologies shows that with no-till the plants are able to photosynthesize better.

All such trials would, however, need be repeated extensively and at different locations and conditions – in full respect of each technology's correct protocol – and be accordingly documented to have formal scientific recognition.

8. CA adoption in Ukraine[31]

Table 6: Ukraine: estimated adoption of resource-saving technologies, million ha, 1990-2009

Technology	1990	2000	2005	2009	Percent of total
Traditional/ploughing	29.5	19.5	10.0	4.9	18
Minimum tillage	2.0	7.5	17.0	21.9	80
No-till	0	0.2	0.5	0.7	2
Total	31.5	27.2	27.5	27.5	100

Source: Team elaborations and Agrosoyuz information, 2013.

In the absence of official statistics, the evolution of land/seed bed preparation technologies in use in Ukraine has been estimated with the advice of farmers[32], practitioners and agriculture machinery suppliers, who all have their own networks and observatories.

This estimate lends itself to some immediate comments:

- resource-saving technologies appear to have picked up steadily since independence with a strong impetus during the last 15 years;
- minimum-tillage is currently the most popular land preparation technology in use;
- traditional land preparation through ploughing has greatly decreased with an apparent trend towards being definitely substituted;
- no-till was introduced in the late 1990s and has been increasing slowly ever since;
- overall cultivated area is struggling to move back to pre-independence levels.

Such trends are similar to those in many other FSU countries. Most of these countries in their progress towards a post-Soviet Union agricultural modernization have had to face challenging issues such as growing erosion, decreasing soil fertility, and soil moisture impoverishment resulting from inadequate land resource management and an increased frequency of drought events. On top of this, countries like the Russian Federation, Kazakhstan and Ukraine which are important international cereal producers and exporters, have also had to struggle to keep up their competiveness in global markets[33]. Depending on the agro-ecological and economic situation of each country, these challenges have had a different importance and level of priority in different countries. In Ukraine, given the prevalence of its black Chernozem soils (which, as discussed, have inherent higher SOM content and more resilient chemical-physical properties), scientists and farmers appear to have prioritized two of the challenges: fighting against erosion and improving farm competitiveness by reducing fuel consumption. Since 2007 MAPFU has promoted the use of resource-saving techniques and technologies[34] as a strategic line of concern and action.

Ukrainian farmers have given precedence to the less demanding – in terms of adaptation requirements – minimum tillage technology as compared with the more complex CA/ no-till.

31 For further details see Annex 5.

32 Personal communication and presentation made by representatives of the JSC AgroSoyuz in Dnipropetrovsk on March 13, 2013.

33 As CIS (Commonwealth of Independent States) agriculture underwent transition following the breakup of the Soviet Union, the Russian Federation, Ukraine and Kazakhstan removed approximately 23 million hectares of arable land from production. This was the largest withdrawal of arable land from production worldwide in recent history. Of the 23 million hectares of arable land excluded from production in the three countries, almost 90% had been used to produce grain, including about 4 million hectares in Ukraine. Some of the non-marginal excluded from production in Ukraine, can be returned to production http://www.fao.org/newsroom/common/ecg/1000808/en/faoebrd.pdf.

34 Agriculture State Programme till 2015; September 19, 2007, N. 1158 (http://minagro.gov.ua/apk?nid=2976).

The main areas of concern (erosion and fuel consumption) seem to have been - from the farmers' point of view - addressed by minimum tillage technology or have become less evident to an extent which is considered quite adequate at current scientific/technical knowledge and investment/organizational capacity levels. Farmers in Ukraine however, do not have sufficient evidence on both the incremental and more sustainable benefits that can accrue by adopting CA on their farms; as well as on the appropriate expedients and adaptations that need to be used in different soil/climate/cropping pattern/organizational situations.

The experience and evidence accumulated by the large farms that have adopted the CA technology are still insufficient for meaningful comparison; data are not regular or have not always been collected consistently. In other words they are not convincing to the broader audience. In turn, scientists have insufficient means, outdated fundamental information (e.g. on the actual state and behaviour of their soils), and have had little to no exposure to international research networks working in this area.

However, meetings that occurred during this study with the most concerned stakeholders – the farmers – confirm that there is growing professional interest in CA/no-till. Ukrainian farmers do not appear at all to be entrenched in old methods and are eager to learn more about what benefits technology can provide for them. It is the same situation for researchers in soil and related sciences. They are ready and willing to invest more time and effort in understanding how technology can best be adapted to the different agro-ecological conditions and specific farming needs of the country.

9. Potential benefits from CA adoption

Table 7: Ukraine: soil erosion under different tillage, 2011/12

Soil practice	Soil erosion (kg/m²/year)
Ploughing	6
Mini-till	4.5
No-till	3

Source: In-field personal communication (SCAI of Donetsk). May, 2013.

CA principles are universally applicable to all agricultural landscapes and land uses with locally adapted practices. CA enhances biodiversity and natural biological processes above and below the ground surface. Soil interventions such as mechanical soil disturbance are reduced to an absolute minimum or avoided[35], and external inputs such as agrochemicals and plant nutrients of mineral or organic origin are applied optimally and in ways and quantities that do not interfere with, or disrupt, the biological processes.

CA facilitates good agronomy, such as timely operations, and improves overall land husbandry for rainfed and irrigated production. Complemented by other known good practices, including the use of good quality seeds, integrated pest, nutrient, weed and water management, etc. CA is a base for the intensification of sustainable agricultural production. It offers increased options for integration of production sectors, such as crop-livestock integration and the integration of trees and pastures into agricultural landscapes.

Specific advantages for Ukraine

CA practices are known to produce several positive outcomes, including the reduction of soil erosion[36]; enhancing moisture retention and minimizing soil compaction[37].

CA is also credited for limiting erosion damage from run-off[38] and flooding. According to on-going field trials in Ukraine[39], CA/no-till produces 50 percent less soil loss per year compared with traditional land preparation technologies and 25 percent less (per year) when compared with minimum tillage.

However, the real effects of CA can be seen better in the medium to longer term[40] as a more sustainable equilibrium is established, which will eventually show that erosion is further reduced at least by 75 percent. There is ample evidence that CA/no-till contributes to the gradual regeneration of the inherent soil structure features and it improves its "anti"- erosion impact, which is eventually further reduced to at least its inherent technical minimum (20-25 percent).

Crop yield variability can also be addressed positively by expanding CA adoption. Crops under continued CA/no-till technology are acknowledged to give higher or at least equal

35 The maximum soil disturbance area that is accepted by the CA protocol is 20-25 percent.

36 Among available literature see e.g.: Javůrek *et al.*, Impact of different soil tillage technologies on soil erosion, 2008 (2): 218-223; Volker Prasuhn, On-farm effects of tillage and crops on soil erosion measured over 10 years in Switzerland, 2011; Wang *et al.*, Dust storm erosion in China, 2006; Sugahara *et al.*, Erosion control on pineapple fields, 2000; Doyle, Reducing erosion in tobacco fields, 1983; etc.

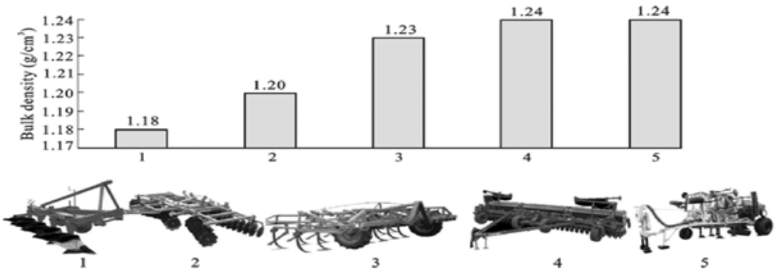
37 Influence of Soil Tillage on Soil Compaction Barbora Badali´kova A.P.Dedousis and T. Bartzanas (eds.), Soil Engineering, Soil Biology 20, DOI 10.1007/978-3-642-03681-1_2, # Springer-Verlag Berlin Heidelberg 2010 http://www.springer.com/cda/content/document/cda_downloaddocument/9783642036804-c1.pdf?SGWID=0-0-45-1001451-p173919206.

38 Stewart B. *et al.*, 2008 "Comparison of runoff and soil erosion from no-till and inversion tillage production systems" http://www.ars.usda.gov/SP2UserFiles/person/6112/sr1083_08.pdf.

39 National Soils and Agro-chemistry Institute in Kharkiv. Personal communication, May 2013.

40 Derpsch, R. *et al.*, Critical Steps to No-Till Adoption, 2008, WASWC. p479 - 495 http://www.rolf-derpsch.com/steps.pdf.

Figure 11: Soil bulk density under different tillage



1. Ploughing 20-22 cm; 2. Disking 10-12 cm; 3. Spring cultivation 6-8 cm; 4. and 5. No-till systems

Source: Kravchenko et al. 2011: Chin. Geogra. Sci. 21(3) 257-266.

yields to that achieved with minimum tillage[41]. The significance of such yields differences depends on the starting point level. In the Ukrainian context the perception of the benefits may be masked by high thresholds that prevail in the country. However, it is proven in several instances that CA/no-till performs better under drought conditions. An assumption can be legitimately made that the yield shortfalls (of 20-25 percent) which occur in drought years in Ukraine, could be mitigated by at least 25-35 percent through CA/no-till adoption, based on what happens in other countries with comparable agro-ecological conditions[42]. In any case, the yields under CA in the medium-term tend to stabilize and significantly reduce the volatility which is usually caused by climatic variation[43]. On a large scale, the impact on Ukrainian economics and on food security is also considerable.

With regard to bulk density, typically this property is influenced by the land preparation technology that is in use (Kravchenko *et al.* 2011: Chin. Geogra. Sci. 21(3) 257-266).

This clearly shows how land management has a strong influence on the behaviour and dynamics of the different soil properties. An appropriate management system can optimize soil conditions. Once again, CA/no-till is an important land resource management technology that is also able to mitigate soil moisture decreases by maximizing SOM, consequently enhancing its physical structure and water holding capacity[44].

From the cost of production savings stand-point, and particularly in terms of fuel consumption there is wide consensus that ploughing is by far the most fuel consuming technology. This is greatly reduced when moving to minimum tillage, and is further reduced with no-till. This is shown by research trials and farm management experiences in Ukraine.

The potential advantages of adopting CA/no-till technology in Ukraine in comparison with minimum tillage have been highlighted throughout this assessment and can be summarized in Table 8.

41 The concept of soil quality : new perspective of nature farming and sustainable agriculture ; Papendick *et al.* 1991 http://www.infrc.or.jp/english/KNF_Data_Base_Web/PDF%20KNF%20Conf%20Data/C4-5-129.pdf.

42 See also "Advancement and impact of conservation agriculture/no-till technology adoption in Kazakhstan": http://www.eastagri.org/publications/pub_docs/Info%20note_Print.pdf; and, "No-till technology in Kazakhstan" by Turi Fileccia (2009), posted on FAO's Conservation Agriculture website. (http://www.fao.org/ag/ca/doc/Importance_Zero_Tillage_Northern_Kazakhstan.pdf).

43 Relationships between winter wheat yields and soil carbon under various tillage systems. O. Mikanová, T. Šimon, M. Javůrek, M. Vach *Crop Research Institute, Prague-Ruzyně, Czech Republic*. Plant Soil Environ., *58*, 2012 (12): 540-544 *www.agriculturejournals.cz/publicFiles/78760.pdf*; Comparison of no-tillage and conventional tillage in the development of sustainable farming systems in the semi-arid tropics. Thigalingam *et al.*, Australian Journal of Experimental Agriculture, 1996, 36, 995-1002. http://www.bobmccown.com/wp-content/uploads/2011/10/112_Thiagalingam_McCown1996No-TillVsConventionalSAT1.pdf; Differential response of wheat to tillage management systems in a semiarid area of Morocco; Rachid Mrabet Field Crops Research 66 (2000) 165±174; Soil properties and crop yields after 11 years of no tillage farming in wheat-maize cropping system in North China Plain; He Jin *et al.* Soil & Tillage Research 113 (2011) 48-54; Effects of Residue Management and Cropping Systems on Wheat Yield Stability in a Semiarid Mediterranean Clay Soil. Mrabe. *American Journal of Plant Sciences*, 2011, 2, 202-216.

44 Impact of three and seven years of no-tillage on the soil water storage, in the plant root zone; Jema *et al.* Soil & Tillage Research 126 (2013) 26-33; Soil fertility distributions in long-term no-till, chisel/disk and mouldboard plough/disk systems; Sjoerd W. *et al*; Soil & Tillage Research 88 (2006) 30-41.

Table 8: Comparison of no-till versus minimum till (potential)

Problem	Through minimum tillage	Through CA/no-till	
Erosion: estimated to cause 500-600 million tonnes of annual soil loss; About 14-15 million hectares are affected by wind/water erosion (update 2013); increasing at a rate of about 60,000-80,000 hectares per year; and equal to 3-30 tonnes/ha of soil per year, depending on regions	Reduced by 25 percent (per ha)	Reduced immediately by 50 percent. With continued CA/no-till: by 75 percent, to a minimum (per ha)	Tonnes of eroded soil: 0.75-7t/ha only
Soil fertility/SOM: 24 million tonnes of annual humus loss (including 964 thousand tonnes of nitrogen, 676 thousand tonnes of phosphorus 9.7 million tonnes of potassium) from tilled land. This is equal to about 5 billion USD	Same as per erosion = 25 percent less	Same as per erosion = 50 percent; 75 percent less	117 USD/ha of NPK Nutrients
Resilience to drought: at current climatic prevailing conditions and in those foreseen due to climate change evaporation rates increase and soil humidity decreases; with dire events every 3-5 years or shorter frequency	Improved moisture retention capacity	Soil nominal moisture retention capacity fully re-established mitigating productivity volatility	See productivity gains
Production volatility: subject to 20 to 25 percent yield reduction in average every 3 years	Insufficient to mitigate significantly production volatility	Production volatility mitigated by 25-35 percent	77 USD/ha every 3 years or 25 USD/ha/year
Cost of production: high fuel consumption with traditional technology (average 100 litres/ ha)	Reduced fuel use by 40 percent = average 60 litres /ha	Reduced fuel use by 60 percent = average 30 litres per ha	Production costs reduction
GHG mitigation, carbon sequestration		Sequestration rates at baseline conditions for 2000-2039	In the short-term: CO_2 Sequestration of 170 kg/ha/year

The above indications (and references) show that CA/no-till technology provides higher benefits even when compared with minimum tillage. This together with a number of other described beneficial effects would justify a gradual but more decisive move towards adoption of this technology in Ukraine.

10. Soil carbon sequestration

Table 9: Ukraine fuel consumption under different land preparation, 2011/12

Soil practice	Fuel consumption (litres/ha)
Ploughing	90-120
Mini-till	60-80
No-till	25-40

Source: Farm managers; Researchers. 2013.

The adoption of CA has an impact in terms of the GHG balance[45]. Emissions are reduced at field level because of very low topsoil disturbance by tillage and thanks to the maintenance of a mulch cover. This results in higher carbon retention capacity in the soil. The reduced mechanized operations also imply a permanent decrease of fossil fuel consumption.

However, in Ukraine, carbon sequestration advantages that derive from the adoption of CA practices appear less evident. As the soil carbon content of the Chernozems is already inherently high, reaching several undertones of carbon per hectare in the top meter, it is really difficult in the short-term to appreciate a variation of a few hundred kilos of carbon. The calculation of soil C sequestration rates in Ukraine would require detailed and high quality determination of soil organic carbon (SOC) and of soil bulk density. When calculating soil C sequestration rates, approaches being used and sampling methods are also crucial. It is very important to take into account any previous change in soil bulk density, and the equivalent depth of the soil sample taken.

Only a few scientific publications are available concerning the evaluation of carbon sequestration performance of reduced-tillage technologies compared with conventional systems in Ukraine. None discuss comparisons with true CA/no-till technology. It also appears that results have been biased by a combination of tillage effects with the use of organic and inorganic fertilizers. In the case of one unpublished trial done at farm level[46] and comparing three technologies (conventional, minimum tillage and no-till), bulk density and "equivalent" soil depth measurements are not reported. Thus, the scientific confidence in the end results is not authoritative.

Only one scientific paper reports C stocks in a typical Chernozem of Ukraine under different long-term tillage systems[47]. However its results cannot be applied to average farm conditions in Ukraine: this experiment applied large amounts of fertilizers and cattle manure (at a rate of 12 tonnes per hectare). Such levels of application are unusual in Ukraine, and they surely had a greater impact on SOM concentration than tillage practices. Thus, the tillage effect was masked in this experiment.

Based on the IPCC global proxies referred to specific climate categories, the corresponding carbon sequestration rates proposed for no-till and residues management category is 0.15 tonnes CO_2-eq/ha/yr^{-} for the cool dry zone; and 0.51 tonnes CO_2-eq /ha/yr for the cool moist zone.

Together with the above fuel savings, the total annual carbon sequestration can be estimated at around 0.5 tonnes CO_2/ha/yr^{-}. These values would generate significant impact only if applied to large areas. A more detailed assessment

45 For more details on this see Annex 6.

46 Done at Agrosoyuz JSC in 2011 and reported in a presentation during May 23rd Round Table discussions in Kyiv, 2013.

47 Kravchenko, Y., Rogovska, N., Petrenko, L., Zhang, X., Song, C. and Chen, Y. 2012. "Quality and dynamics of soil organic matter in a typical Chernozem of Ukraine under different long-term tillage systems". In: Can. J. Soil Sci. 92: 429-438.

of CA adoption should be compared with the business as usual scenario of suboptimal land management practices meaning: continued erosion; sustained loss of SOC; and decreased organic fertilization.

CA/no-till is a long-term undertaking. Experience from countries[48] and farms that have successfully moved to CA/no-till show that it is not just a gradual improvement from minimum tillage, but a qualitative jump ahead in terms of production, economic and environmental benefits.

Phasing CA adoption

So far, this assessment acknowledges the following key facts and a few specific assumptions:

(i) almost one-half (19 million hectares) of the arable land is located in the Steppe AEZ of Ukraine;

(ii) about 60 percent of the arable land in the country is managed by agricultural enterprises; over half of these are situated in the Steppe AEZ;

(iii) the Steppe area produces 45 percent of wheat, 15 percent of corn and 47 percent of sunflower output;

(iv) the Steppe area is the most affected by erosion, soil fertility loss, and negative climate change impacts;

(v) the Steppe area has highest output volatility;

(vi) as of 2012, CA/no-till adoption is an undertaking exclusively of large organized farms (> 4 000 hectares); it is noted that a majority of such farmland (estimated at 70 percent) is located in the Steppe area;

(vii) there is a good level of "readiness to convert" given the existing capacity of direct seeding machinery among large agricultural enterprises: over two thousand 6-12 metre wide seeders have been sold in Ukraine during the last five years, each capable of operating in average 2 000 hectares. It is assumed that 50 percent of these are in the Steppe AEZ.

48 Current status of adoption of no-till farming in the world and some of its main benefits; Rolf Derpsch, March, 2010 Int. J Agric. &.Biol Eng., Vol. 3 No.1.

All such aspects would justify the prioritization of Climate Smart Agriculture measures and specifically, the expansion of CA/no-till investment in the Steppe area of Ukraine.

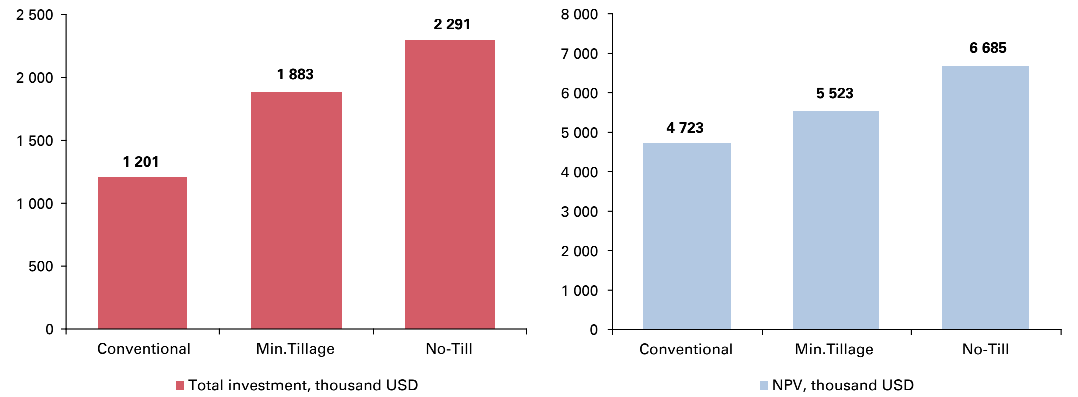
In the short-term (three to five years), if adequate financial resources are made available and *ad hoc* development interventions are supported, it is assumed that the CA/no-till area will grow to three million hectares in the Steppe area. This criteria of prioritization implies that the agricultural enterprises with an operational cropping area of 4 000 hectares and above, would act as first champions in CA technology adoption.

In the medium-term (six to ten years), with continued state support, and the greater evidence and awareness of the benefits for farmers, the entire Steppe area managed by agricultural enterprises would probably take up CA; starting with a further 3 million hectares (enterprises with 2 000 ha and above), and eventually including the total 9 million ha managed by enterprises.

In the longer term but it could happen sooner – all farmland including the Forest Steppe area operated by enterprises – i.e. 17 million hectares, has the potential to adopt CA.

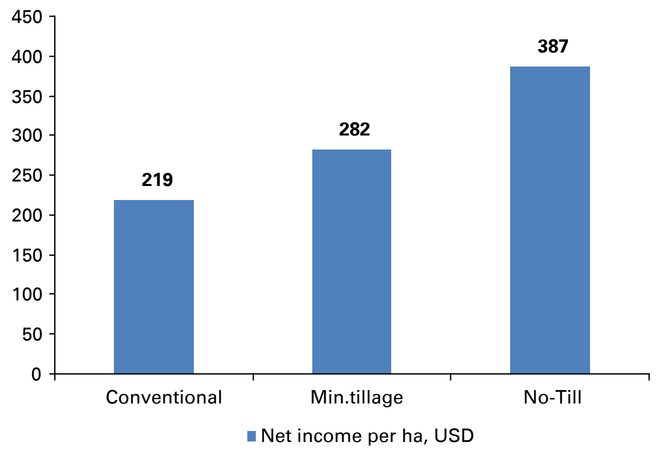
11. Benefits and economics of CA

Figure 12: Total investment and net present value



Source: Team estimates.

Figure 13: Net income per hectare by technology



Source: Team estimates.

The potential benefits of large-scale adoption of CA in Ukraine have been carefully quantified at three levels: farm/enterprise, national, and global.

Farm/enterprise level

The adoption of CA technology is expected to lead to significant economic and financial efficiency in grain and oil seeds production by:

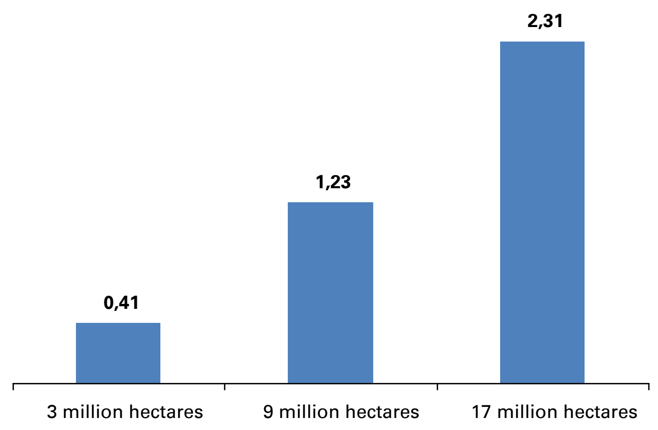
- increasing output stability;
- decreasing inputs use and cost;
- increasing productivity or efficiency; and

The performance of a 4 000 hectare agriculture enterprise in comparison with other technology use is clear, as can be seen in Figure 12 and Figure 13.

With almost double investment compared with conventional tillage, an enterprise that adopts CA/no-till can expect a net present value (NPV) of over USD 6.6 million; and about USD 390 in terms of net income per ha/per year.

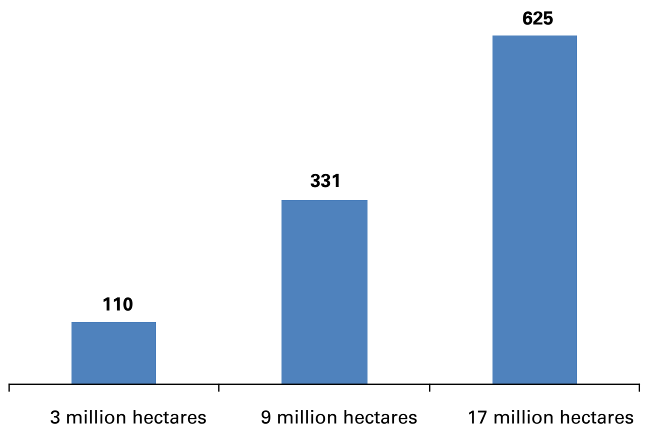
Based on the figures assumed in this analysis (3 million hectares in the short to medium-term; 9 million hectares in the medium-term; and 17 million hectares in the longer term), the

Figure 14: Incremental net income by technology



Source: Team estimates.

Figure 15: Annual fuel savings by technology



Source: Team estimates.

average accumulated benefit from the introduction CA/no-till (intended as additional net income of agricultural enterprises) would amount to:

- short-term: USD 0.41 billion;
- medium-term: USD 1.23 billion;
- long-term: USD 2.31 billion.

Importantly, the decreased annual fuel consumption cost which is considered a farm/ enterprise level benefit would be:

- short-term: USD 110 million saved;
- medium-term: USD 331 million saved;
- long-term, USD 625 million saved.

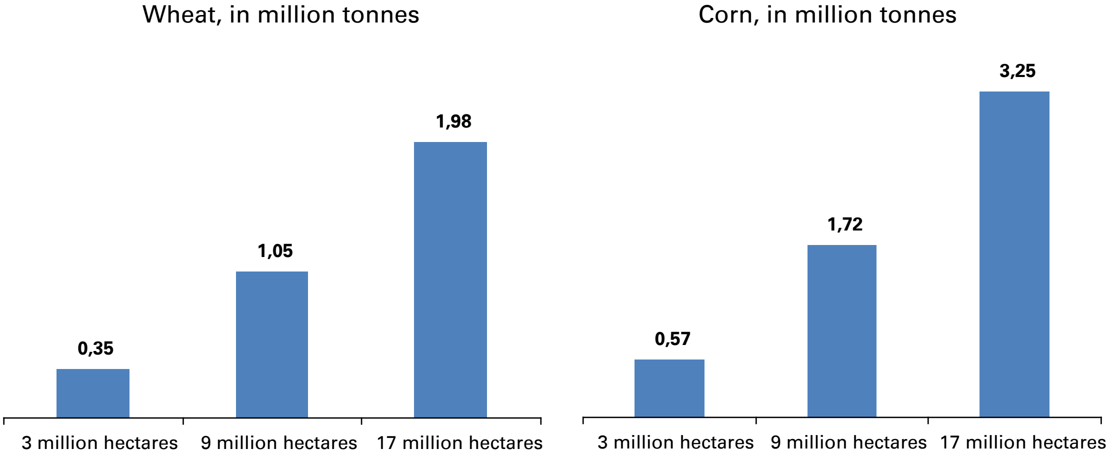
A sensitivity analysis was also performed. A CA/ no-till farm would probably remain profitable even if grain sale prices fell by 34 percent from the baseline scenario. In the case of conventional tillage technology, the analysis generates a negative return (NPV) if prices decrease by more than 24 percent.

National level

The main benefits at the national level consist essentially in reduced cereal output volatility. The estimated additional output of cereals (wheat and corn) available during drought years (every three years) would be:

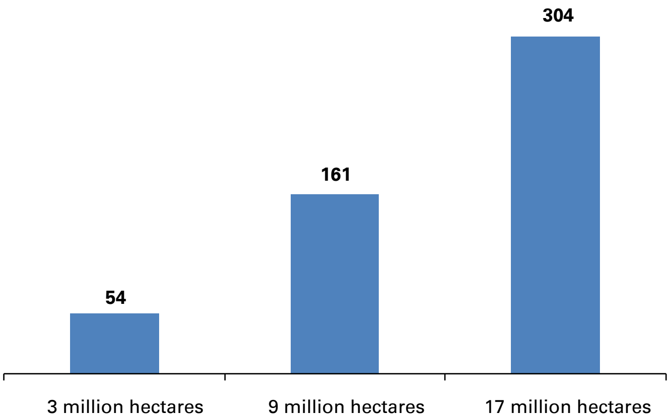
- short-term: 0.3 million tonnes of wheat and 0.6 million tonnes of corn;
- medium-term: 1 million tonnes of wheat and 1.7 million tonnes ofcorn;
- long-term: 2 million tonnes of wheat and 3.3 million tonnes of corn.

Figure 16: Incremental production by scenario



Source: FAO OECD Agricultural Outlook 2013-22.

Figure 17: Incremental value by scenario



Source: Team estimates

This additional supply of cereals is expected to generate off-farm benefits (mainly to traders and intermediaries). In drought years (once every three years) these additional benefits are estimated at:

- short-term: USD 54 million;
- medium-term: USD 161 million;
- long-term: USD 304 million.

More significant in value terms is the decreased soil fertility loss. This would reduce the equivalent nutrient investment (which is otherwise required to keep up crop productivity) by USD 117/ha giving a total saving of:

- short-term: USD 0.35 billion;
- medium-term: USD 1.05 billion;
- long-term: USD 1.99 billion.

Global level

At a global level, the benefit is estimated in terms of improved food security during the drought years (every three years). Considering a consumption of 130 kg of cereals/per capita/ per year (FAO/WFP average calorie intake), the increased supply of cereals deriving from CA/no-till area would be able to a feed further:

- short-term: 5.4 million people;
- medium-term: 16.1 million people;
- long-term: 30.4 million people.

Figure 18: Nutrient savings by scenario

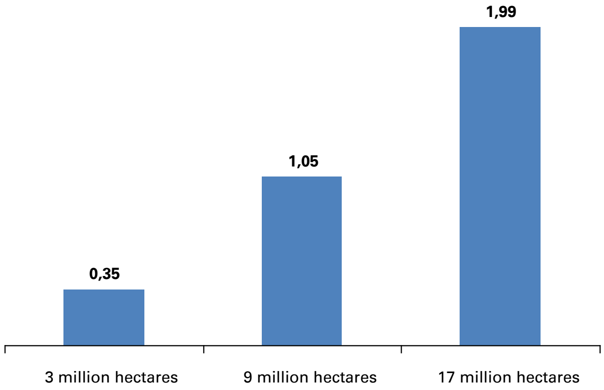
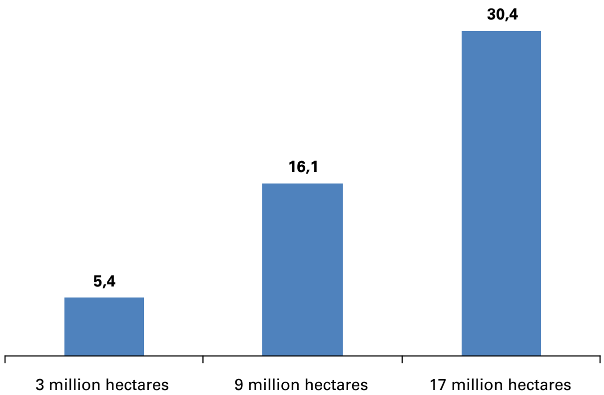


Figure 19: Incremental food security by scenario



Source: Team estimates.

Benefits in terms of carbon sequestration and decreased emissions have been calculated using EX-ACT[49]. They were estimated as three snapshots according to the three above scenarios:

- adoption of CA in 3 million ha: 1.5 million tonnes of CO_2e sequestered per year, equivalent to the emissions of 0.3 million cars
- adoption of CA in 9 million ha: 4.4 million tonnes of CO_2e sequestered per year, equivalent to the emissions of 0.9 million cars
- adoption of CA in 17 million ha: 8.3 million tonnes of CO_2e sequestered per year, equivalent to the emissions of 1.7 million cars

The market values of the above carbon emissions are difficult to estimate. Carbon markets are diverse, unstable and unreliable. The price of a tonne of CO_2 can range from USD 0.5 per tonne according to the NASDAQ Certified Emission Reduction to USD 4.44 according to EU CO_2 Allowances. The economic value can range from 15 to 150 USD per tonne of CO_2.

49 EX-ACT is a tool developed by FAO and aimed at providing ex-ante estimates of the impact of agriculture and forestry development projects on GHG emissions and carbon sequestration, indicating its effects on the C-balance, an indicator of the mitigation potential of the project.

12. Next steps

The potential benefits from large scale adoption of CA are summarized in Table 1 and the risks caused by a changing climate should constitute a strong incentive to increase efforts to increase soil fertility and strengthen climate resilience. A comprehensive plan should be designed and implemented to achieve such important results. The list below is a set of steps that would be required.

Verification of preliminary estimates

The FAO preliminary assessment would benefit from a more detailed follow-up investigation to address areas such as: detailed on-farm productivity, economic and environmental analyses for technology comparison, assessment of agricultural machinery capacity and market, evaluation of erosion impact on river systems and water bodies' siltation.

Land markets

Agricultural land markets in Ukraine suffer several weaknesses. This complex issue is a high priority of the Government which the World Bank has been supporting for quite some time. It is important to increase the efforts to improve confidence in long-term use of land so as to create incentive for farmers to invest in long-term soil fertility.

Agricultural technology/advisory services

At the moment, agro-enterprises are excessively dependent on suppliers for technical assistance. To increase the attention paid to soil fertility it is essential to develop a programme of agricultural technology or advisory services which could address soil fertility concerns.

Financial services

Access to affordable financing is a key constraint for Ukrainian agricultural enterprises. Any approach to facilitate access to finance should favour those enterprises which invest in environmentally friendly approaches such as CA.

Agricultural insurances charge higher premiums to those agro-enterprises which apply CA because this technology is less known. The Government should encourage dialogue between research centres and insurance providers so that the bias against this technology is eliminated;

Risk management

It will be necessary to work with the research and farm community to improve the quality of information on the estimated potential impact of climate change on agriculture, differentiating risks and adaptation approaches by agro-ecological region.

Food security

In order to improve food security, it will be necessary to strengthen incentives for adopting technologies to maintain soil fertility and reduce the volatility of agricultural production, such as CA with no-till.

Implementing the above steps does require additional financing. In consideration of the global benefits that the proposed actions could generate, there are some sources of international financing which Ukraine could apply for. For instance, there is available grant funding from the GEF and from the Adaptation Fund for Ukraine:

- The GEF will start a new funding period in July 2014 (called GEF-6), where there are funds available for Ukraine to address issues related to climate change (USD 17.4 million) and land degradation (USD 2.9 million). The GEF does require co-financing, usually at least four times that of the GEF grant amount;
- The Adaptation Fund has a grant of up to USD 10 million available for Ukraine.

The Adaptation Fund can finance adaptation investments on a grant basis up to USD 10 million per country. The preparation process has some similarities to the GEF project cycle, a known process in Ukraine. The Adaptation Fund has two windows:

(i) the Multilateral Implementation Entities, where international intermediaries such as the United Nations Development Programme, World Bank, the United Nations Environment Programme and others can participate in a tri-partite contract; and

(ii) the Regional or National Implementation Entities. This requires a bilateral contract between the Grantee and Grantor, without a multilateral agency as intermediary.

A period of at least one year is needed to prepare and receive approval for such a proposal. The following steps are necessary:

(i) Nomination of the Adaptation Fund Focal Point at National Level, often the head of the United Nations Convention to Combat Desertification, or similar.

(ii) Accreditation of the National Implementing Entry. This is a complex step which requires accrediting several areas including financial management, procurement, project supervision, anti-corruption, and transparency. Countries where a local agency has been accredited: India, Jordan, Uruguay, Argentina, Jamaica, Belize, Senegal, South Africa, Rwanda, Benin. Macedonia should have an advantage here since the Paying Agency has already significant experience under the European Union Accreditation Process.

(iii) Preparation of a project concept of about 20 to 30 pages. The project concept does not need to have a detailed budget, detailed result framework, or economic analysis, but should focus mostly on justification and rationale. After the project concept has been accepted, the country can access a USD 30 000 grant for preparation.

(iv) Preparation of the full proposal. This is quite demanding and often requires much correspondence with the Secretariat.

The Adaptation Fund has already funded many proposals to help the agriculture and food sector to adapt to climate change. A large number of Climate Smart Agriculture or food security proposals similar to CA have been financed. This should thus represent an interesting funding option, which may complement GEF funding.

Annex 1 - Ukrainian soils

Dominant soil types

Due to the large size of the country (circa 60 million hectares) and the variety of natural soil-forming factors (climate, geology, native vegetation, relief etc), Ukraine has a large diversity of soil types. According to the European Soil Atlas (Figure 20), 15 Reference Groups (RGs), which account for nearly one-half of the RGs of the World Reference Base (WRB), are found in the country.

The north-eastern region is covered by Albeluvisols, Phaeozems and Histosols, which are common for mixed coniferous-deciduous and deciduous forests of the cold temperate regions of the Russian plain. The north-western part of Ukraine is dominated by Histosols. Histosols and Gleysols occupy the swampy depression shared with Belarus called Polissya also known as the Forest AEZ. The eastern and central parts of the country are covered mainly by Chernozems. Chernozems combined with Fluvisols are found in the flat valleys of the Dnepr and its tributaries. Chernozems are associated with Phaeozems, and to a lesser extent with Cambisols, on the Podolskaja and Predneprovskaja uplands of the central part. The southern region is a huge area of homogeneous Chernozems bordered on the south by the Krym peninsula. The depression between the peninsula and the Chernozems presents a mixture of saline soils. Table 10 provides a tentative equivalent of the FAO WRD base in other soil classifications used in most documents concerning Ukraine.

In terms of absolute coverage Chernozems occupy about half of the country, followed by Phaeozems and Albeluvisols, each corresponding to about 14 percent of the country. Chernozems and similar (Phaeozems and Kastanozems), are classified as Mollisols in the USDA Soil Taxonomy. Chernozems are considered to be amongst the most productive soil types in the world. They are characteristic of the long-grass steppe regions,

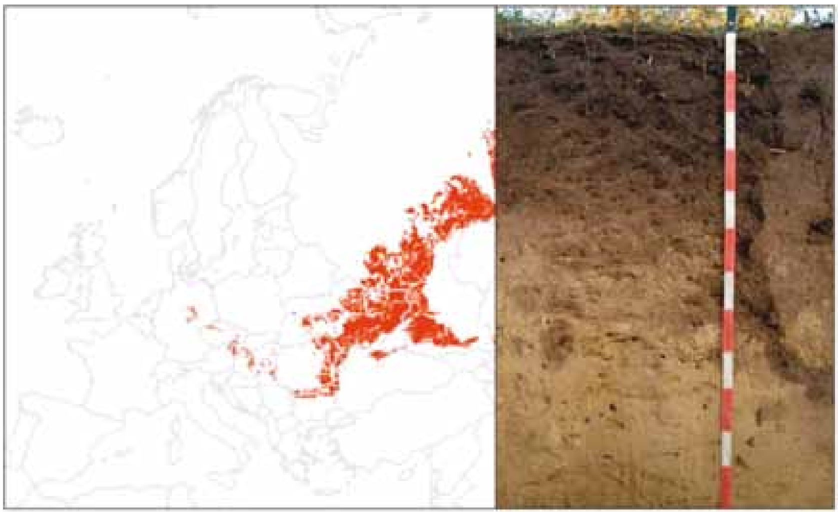
Table 10: Tentative correspondence of the main soil types in Ukraine

Reference group of the WRB	USDA soil taxonomy	Ukrainian names	Observations
Albeluvisols	Alfisols (aqualfs, cryalfs and udalfs suborders)	Peat-boggy soils, soddy gleyed soils	Agricultural suitability is limited because of their acidity, low nutrient levels, and tillage and drainage problems.
Cambisols	Inceptisols	Soddy brown soils	Cambisols generally make good agricultural land and are used intensively.
Chernozems	Mollisols	Чорноземи or Black soils	They have deep, high organic matter, nutrient-enriched surface soil (A horizon), typically between 60-80 cm in depth. This fertile surface horizon results from the long-term addition of organic materials derived from plant roots, and typically have soft, granular, soil structure.
Fluvisols	Entisols (Fluvents and Fluvaquents)	Meadow soils on alluvial deposits, meadow-swamp	They correspond to Alluvial plains, river fans, valleys and marshes; many Fluvisols under natural conditions are flooded periodically.
Histosols	Histosols	Peat	Soil consisting primarily of organic materials They have very low bulk density and are poorly drained because the organic matter holds water very well. For cultivation, most of them need to be drained and, normally, also limed and fertilized.
Gleysols	Different orders with an "aquic" condition	Light grey and grey Podzolized soils, Meadow soils	Soil often saturated with groundwater for long periods. Thus, the main obstacle to their utilization is the necessity to install a drainage system to lower the groundwater table.
Phaeozems and Kastanozems	Mollisols (Udolls and Albolls)	Meadow-chernozemic soils, chesnut soils, Solonetzs	Phaeozems and Kastanozems are much like Chernozems but they are leached more intensively. Phaeozems are porous, fertile soils and make excellent farmland. Most are slightly acid or neutral.

Figure 20: Distribution of soil types in Ukraine

Source: Adapted from Plate 18 of the Soil Atlas of Europe.

Figure 21: Distribution of Chernozems in Europe and typical Chernozem profile



Source: Soil Atlas of Europe.

especially in Eastern Europe, Ukraine and the Russian Federation.

The distribution of the soils in Ukraine shows common patterns with the country's AEZ (Figure 2). The Forest AEZ corresponds to 19 percent of the territory. The Forest-Steppe zone occupies 34 percent. The Steppe zone situated in southern Ukraine occupies about 40 percent of the territory. See also Table 11 first column) that indicates the coverage of agricultural lands per AEZ. Chernozems are typical of the Steppe AEZ (together with Kastanozems in the southern part), and of the Forest-Steppe AEZ together with Phaeozems.

The first four soil types, corresponding to the Chernozems, Kastanozems and Phaeozems of the WRB classification (see above) represent around two thirds of the soil coverage. These soils contain a high percentage of arable soils, close to 90 percent for the different Chernozems types.

Arable soils cover 78.5 percent (about 31 million ha) of Ukrainian soils and are mostly Chernozem soils.

Main properties of the soils

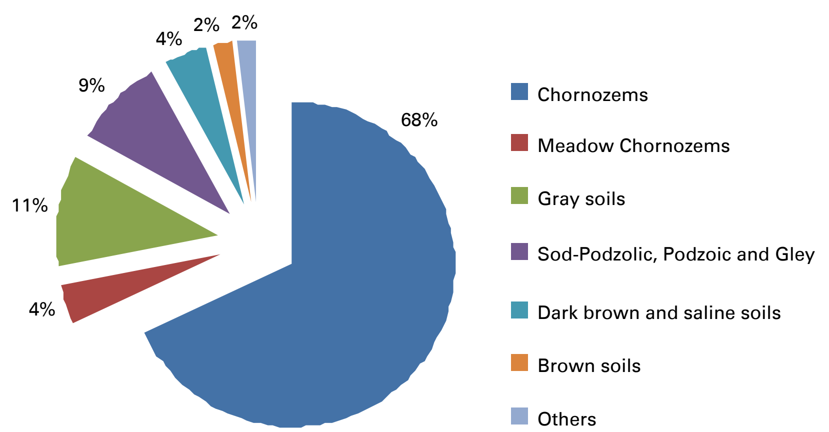
This section will focus on the most dominant soil type by area, that also correspond to largest extent of arable lands, that corresponds to the

Table 11: Ukraine: soil distribution

Soils (based on Ukrainian classification)	Agricultural lands (thousands ha)	Arable (%)
Chernozem podzolic	3 418.7	91.6
Chernozem typical	5 779.6	91.8
Chernozem ordinary	10 488.6	88.3
Chernozem southern	3 639.9	88.8
Meadow chernozem and chernozem-meadow	2 038.9	60.0
Light-grey forest, forest grey, dark grey podzolic	4 333.4	80.5
Sod-podzolic, podzolic, grey	3 850.2	74.1
Dark brown, chestnut saline, saline meadow-chestnut, chestnut salt	1 382.9	80.0
Brown (podzolic, podzolic, meadow brownsoil-podzolic gley)	1 110.0	43.9
Brown	48.5	26.2
Meadow and marsh and swamp	975.3	7.9
Alluvial meadow and meadow-swamp	781.9	18.8
Peat from lowland	559.4	14.9
Sod-sandy and sandy-coherently and sand	505.5	24.2

Source: Balyuk, 2013.

Figure 22: Ukraine: share of the arable soils



Source: Based on Table 11.

Chernozems, Phaeozems and Kastanozems (all being grouped under Mollisols in USDA Soil Taxonomy).

In terms of texture, these soils vary from light loam to medium clay. Coarse silt and clay are thus dominant soil particles, but distributions might differ. Typically texture becomes heavier from the north to the south: The percentage of particles (< 0.01 mm) varies from 25 to65 percent from the Wet Forest-Steppe to the South Steppe (Kravchenko *et al.*, 2011).

According to Krupskiy and Polupan[50] (1979) the nominal SOM content of Chernozems increases from 5.2 percent in the Wet Forest-Steppe to 5.7 percent in the Forest-Steppe and 6.2 percent in the Steppe, but decreases to 3.4 percent in South Steppe. Fertility of the Chernozem soils varies according to their location, following the same pattern, decreasing from Forest-Steppe to Southern Steppe (Table 12).

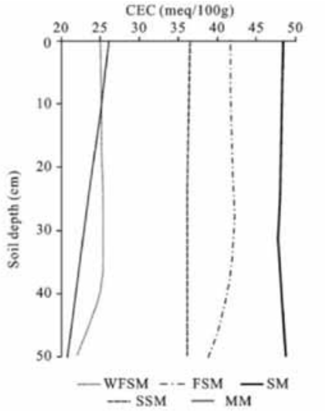
50 Krupskiy N K, Polupan N I, 1979. Soil Atlas of USSR. USSR, pages 48-101 (cited in Kravchenko *et al.* 2011: Chin. Geogra. Sci. 21(3) 257-266).

Table 12: Agropotential of Chernozem soil for winter wheat

Zone	Soil	Agropotential		Arable (%)
		Natural q/ha	Optimal q/ha	
Forest-Steppe	Chernozem podzolic	30 - 38	40 - 48	8.6
	Chernozem Typical	32 - 36	38 - 45.2	14.5
	Typical Chernozem and Meadow	30 - 36	54 - 64	1.0
Steppe	Chernozem ordinary	23.2 - 34	31.6 - 40	26.3
	Chernozem Southern	18 - 25.2	22 - 31.2	9.1

Source: Balyuk, 2013.

Figure 23: Cation exchange capacity (CEC) in Ukrainian Chernozems [51]



Source: Fridland et al., 1981.

This behaviour is partly dependent on the CEC of the soils. CEC is the maximum quantity of total cations that a particular soil is capable of holding, at a given pH value, and which available for exchange with the soil solution. Thus CEC correlates with soil fertility. CEC is dependent on the mineral matrix but also the amount and quality of SOM. Soil organic materials raise the CEC by increasing the available negative charges. Consequently, organic matter build-up in soil usually improves soil fertility.

Physical properties of the Chernozem soils are also important for their agricultural use. Soil bulk density is an indirect measure of soil pore space which depends on soil organic matter content and texture. It has been reported that the favourable range for plant growth is 0.9-1.3 g/cm^3 in Ukrainian Chernozems (Fridland *et al.*, 1981). But typically this property will rely more on the management of the soil than its location in the different AEZ (Figure 25).

It is important to stress that soil management will have a strong influence on the behaviour and dynamics of the different soil properties. Management can imply either antagonist or synergic patterns among the different soil properties. This means it is necessary to fine tune soil management in order to optimize soil conditions for sustainable productivity.

Historically, soil properties have also been impacted by the different management operations used in the past (Table 13).

The major changes observed were the decline in SOM (Figure 25) and soil thickness, while water and wind erosion as well as soil compaction are also becoming serious (see degradation section below).

Kravchenko *et al.* (2011) also reported a decrease in SOM of 22 percent of the original levels in the

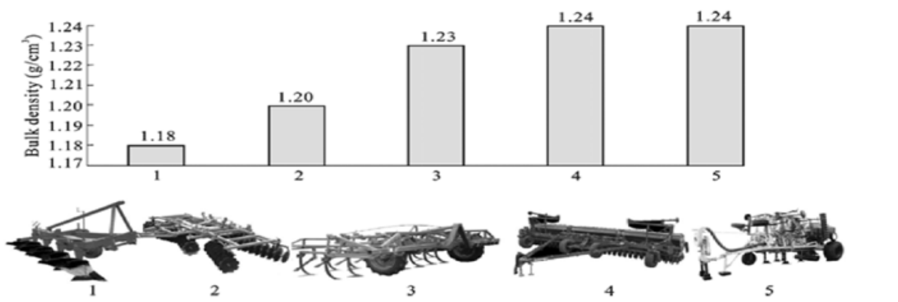
51 WFSM: Wet Forest-Steppe Mollisols, FSM: Forest-Steppe Mollisols, SM: Steppe Mollisols, SSM: South Steppe Mollisols.

Table 13: Evolution of various inputs to agricultural soils in Ukraine, 1986-2010

Management operation	Periods of time			
	1986-1990	1996-2000	2001-2005	2006-2010
Application of chemical fertilizers (kg/ha)	148	16	24	40
Application of organic matter (millions tonnes)	278	52	19	21
Liming of acid soils (thousands ha)	1 548	53	32	36

Source: Balyuk, 2013.

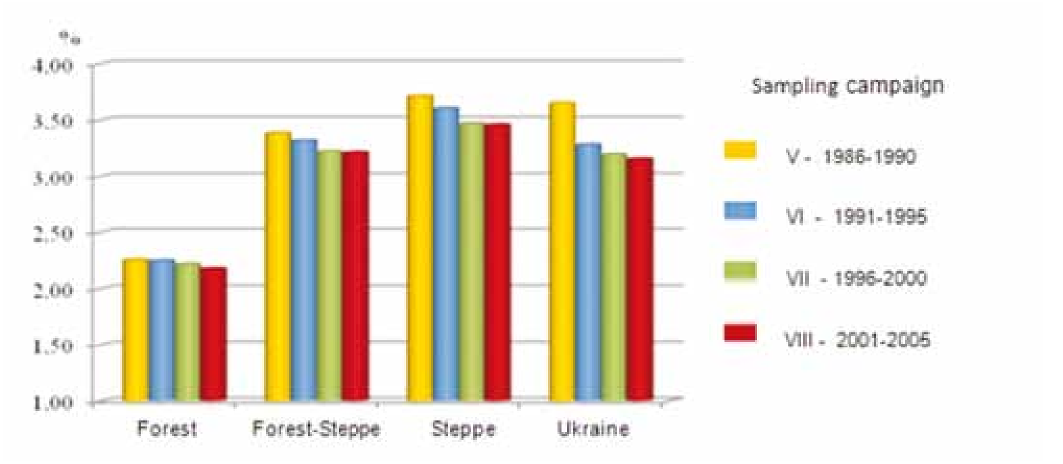
Figure 24: Bulk density in Ukrainian Chernozem by tillage systems



1. Ploughing 20-22 cm; 2. Disking 10-12 cm; 3. Spring cultivation 6-8 cm; 4. and 5. No-till systems

Source: Kravchenko et al. 2011: Chin. Geogra. Sci. 21(3) 257-266.

Figure 25: Evolution of soil organic carbon content in Ukrainian soils for the various AEZ



Source: Data reported by Balayev2013..

Forest Steppe zone, 19.5 percent in the Steppe zone and 19 percent in the Forest Zone in Ukraine.

There are strong correlations (even if these correlations change according to the soil and other conditions) between the SOM content and other properties, including fertility. Therefore, practices that favour the conservation of soil resources are urgently needed to guarantee sustainable production.

Soil degradation

Like most cultivated soils around the world, Ukrainian soils suffered and are still exposed to different forms of soil degradation. The dominant forms of degradation are summarized in Table 14.

The geographical distribution of the different forms of degradation will depend on different factors such as the climate and the soil type, thus there are zones of degradation as reported for water erosion (Table 15 and Figure 26).

Table 14: Type of soil degradation affecting more than 1 percent of total area

Types of soil degradation	Share of the degradation level (% of total area)			
	low	medium	strong	total
Loss of humus and nutrient matter	12	30	1	43
Soil compaction	10	28	1	39
Sealing and soil crust formation	12	25	1	38
Water erosion	3	13	1	17
Acidification	5	9	0	14
Water excess	6	6	2	14
Contamination by radio nuclides	5	6	0.1	11.1
Wind erosion affecting the top soil	1	9	1	11
Pollution by pesticides and other organic contaminants	2	7	0.3	9.3
Contamination with heavy metals	0.5	7	0.5	8
Salinization, alkalization	1	3	0.1	4.1
Gully erosion (ravines formation)	0	1	2	3
Side effects of water erosion (siltation of reservoirs)	1	1	1	3

Source: Morozov, 2007.

Table 15: Soil cover degradation in agricultural land by AEZ

Zone	Area		Eroded land			Acid land	Salted land	Other (water saturation, marshes, stony)
	thousand ha	%	by wind	by water	both by wind and water			
Forest	5 616.6	13.5	4.2	0.9	-	5.4	0.5	3.3
Forest-Steppe	16 854.4	40.6	7.6	11.6	0.1	17.8	2.9	4.0
Steppe	18 993.5	45.8	34.9	19.5	4.9	2.6	8.1	2.8
Total	**41 464.5**	**100**	**46.7**	**32.0**	**5.0**	**25.8**	**11.5**	**10.2**

Source: Balayev, 2013.

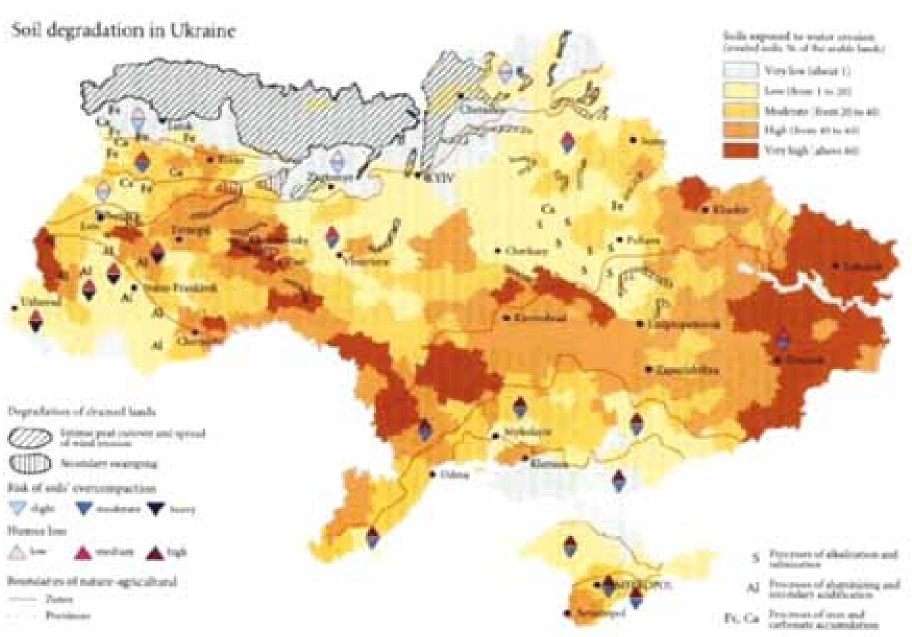
According to a 2007 Country Review from the World Bank[52] "the impact of the Ukrainian agricultural production system on the environment is estimated to cause 35-40 percent of the total environmental degradation […] The main environmental problems caused by agriculture in Ukraine include soil erosion and degradation, loss of biodiversity, water contamination (both surface and groundwater), mismanaged agricultural waste, soil contamination, and inadequate storage of obsolete pesticides."

According to Dr Balyuk, Head of NSC Institute for Soil Sciences and Agrochemistry Research, named after O.N. Sokolovskyj, the predominant reasons causing soil degradation are:

- increasing economic pressure on soils for productivity;
- lower level of conservation areas (nature reserves and other protected areas for recreational, health and historical-cultural purposes);
- absence of strong adequate state, regional and local programmes; and
- insufficient level of the legislative protection of soils.

52 "Integrating Environment into Agriculture and Forestry: Progress and Prospects in Eastern Europe and Central Asia". Volume II - Ukraine. www.worldbank.org/eca/environmentintegration.

Figure 26: Map of soil degradation in Ukraine



Source: Balayev, 2013.

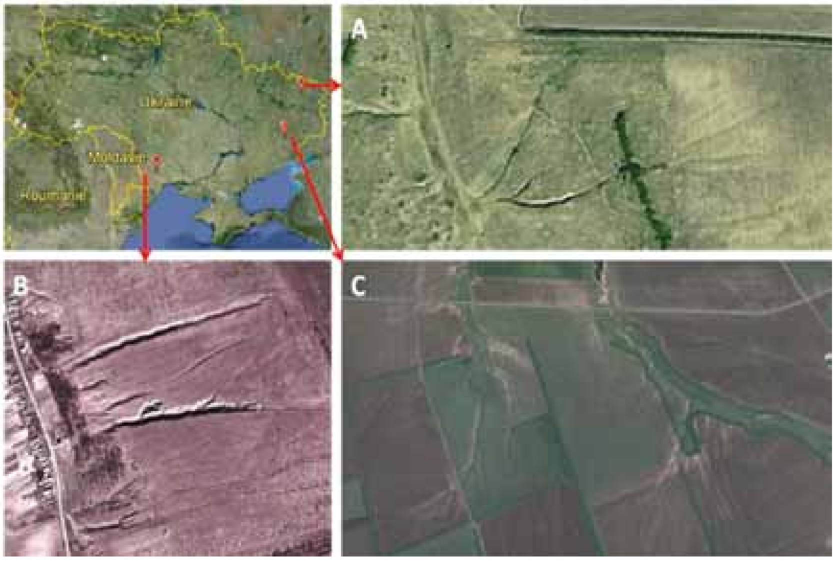
Climate change impact

Smith and his colleagues (Smith *et al.*, 2007) estimated the soil organic carbon status under different climate change scenarios from the IPCC and the climate model HadCM3 from the Hadley Center.

Their results suggested that soil organic carbon will be lost under all climate scenarios. However, they also showed that optimal management will be able to reduce this loss of SOC by up to 44 percent compared with usual management practices.

Annex 2 - Erosion of Ukrainian soils

Figure 27: Ukraine: soil erosion is visible from satellites



Source: Google Earth © (Obtained 17 June 2013).

Soil erosion is the most important form of soil degradation in Ukraine. Erosion can be caused by wind or water. Both forms occur in Ukraine, and sometimes the combination of both. Erosion has associated negative impacts at field and farm level, such as decrease of soil fertility and decrease of crop yields, but also at the landscape scale:

- decrease in water quality from nutrient leaching;
- siltation of rivers and reservoirs; and
- loss of rural income.

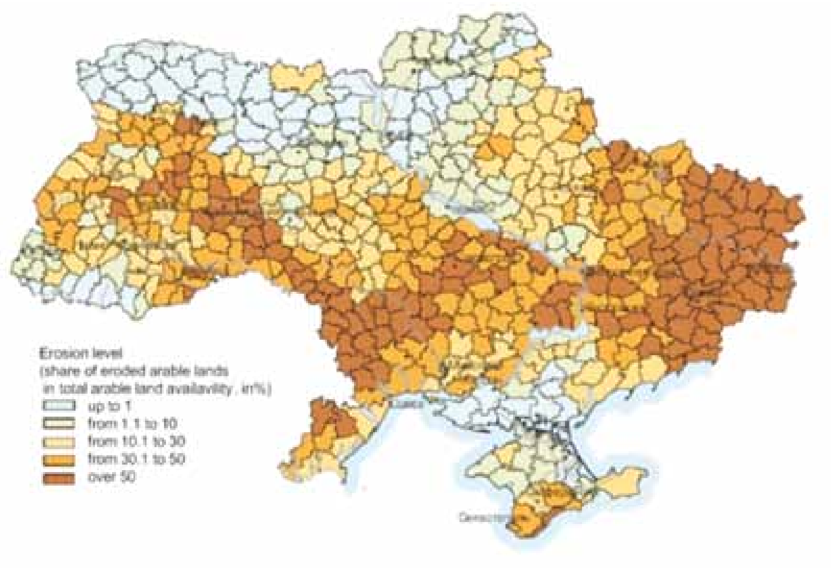
In the past, Ukraine was considered the granary of the former Soviet Union. However, high agricultural production, mostly in an intensive manner, caused serious erosion. According to FAO[53], annual soil losses during that period were as much as 600 million tonnes, including 20-30 million tonnes of humus, and cost the country more than USD 1.6 billion annually. An estimated 40 percent of the country territory is now eroded at different levels of severity (Figure 28), and an additional 40 percent is prone to wind and water erosion. A 1996 study by the State Committee of Land Resources reported that 13.2 million ha were exposed to water erosion, and 1.7 million ha were exposed to wind erosion[54]. It was estimated that these figures would increase by about 60 000-80 000 ha per year. At this rate erosion would affect about 14 to 14.5 million ha in 2013. Erosion is exacerbated by the recent significant decrease in the application of mineral and organic fertilizers, which has caused a sharp decline in soil humus content, as reported in Annex 2.

The map above represents the percentage of arable land affected by erosion, but not its severity level. Some authors proposed an evaluation of the erosion level in terms of intensity. For instance the paper by Belolipskii

53 Bogovin A.V. 2006. Country Pasture/Forage Resource Profiles: Ukraine." FAO. http://www.fao.org/ag/agp/agpc/doc/counprof/ukraine/ukraine.htm.

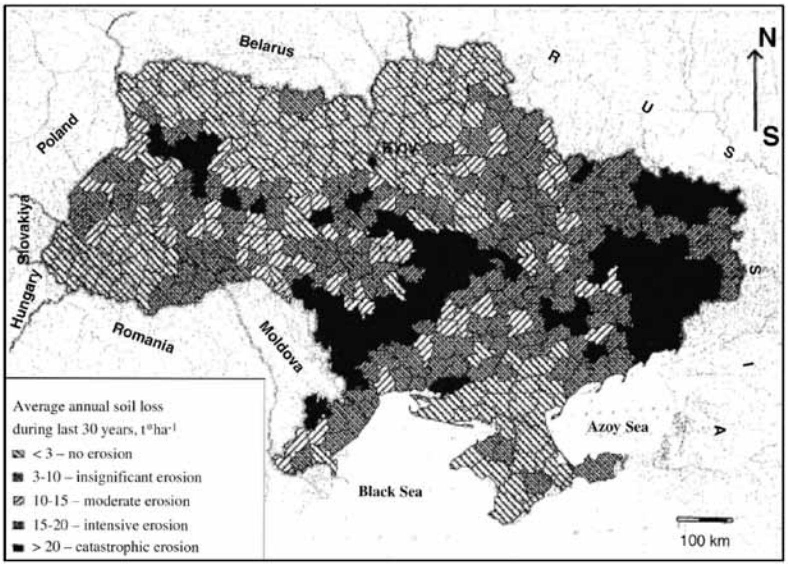
54 World Bank. 2007. Integrating Environment into Agriculture and Forestry Progress and Prospects in Eastern Europe and Central Asia. Volume II. Ukraine, Country Review. 22 pp. www.worldbank.org/eca/environmentintegration.

Figure 28: Ukraine: erosion map



Source: Bulygin, 2006.

Figure 29: Ukraine: arable land annual soil loss during the last 30 years



Source: Bulygin, 2006.

and Bulygin[55] divides the Ukrainian steppe into zones according to the potential runoff manifestation degree, i.e. the potential severity level (see Figure 29).

Bulygin (2006) reported that according to data from the Ministry of Agriculture, about 500 million tonnes of soil on average are lost from Ukrainian arable land yearly, corresponding to 23.9 million tonnes of humus, 964 thousand tonnes of nitrogen, 676 thousand tonnes of phosphorus and 9.7 million tonnes of potassium. But Bulygin (2006) also recognized that the method used to derive the map in Figure 29, might not be appropriate for the Carpathian and Crimean mountains. The yearly soil loss averages 8-30 tonnes per hectare depending on the region. The same publication also reported that "According to the data obtained from the Institute of Soil Conservation (Lugansk), the shortfall of grain production resulting from soil degradation is 8.6 million tonnes."

55 Belolipskii V.A., Bulygin S.Y. 2009. An Ecological and Hydrological Analysis of Soil- and Water-Protective Agrolandscapes in Ukraine. Eurasian Soil Science, Vol. 42, No. 6, pp. 682-692. DOI: 10.1134/S1064229309060143.

Table 16: Soil properties according to erosion levels and depths

Erosion severity	pH (H_2O)	Carbonate	Humus	Sand	Silt	Clay (USDA)	Clay (FSU)	N	Min N	Nitr. Ener.	Urease	C:N ratio
E0 (none)	7.9	7.7	2.38	7.2	51.4	41.4	56.4	0.17	20.7	13.7	126	7.67
E1 (mild)	8.51	10.0	1.73	11.5	66.8	21.8	34.7	0.13	16.1	9.5	135	6.78
E2 (moderate)	8.66	13.8	1.03	5.6	66.1	28.4	47.9	0.11	10.3	6.2	96	4.72
Mean	8.36	10.5	1.71	8.1	61.4	30.5	46.3	0.14	15.7	9.8	119	6.39
LSD* (Erosion)	0.29	2.7	0.33	4.3	5.8	3.3	2.3	0.02	3.6	2.7	33	1.14

Mean soil properties for different erosion severities and different depths.
*LSD = Least significant Difference, it is the minimum difference to have a statistically significant difference between two values.

Quantities are in % mg/kg or mg NO3/kg.

Table 17: Yields according to various treatments

Treatment	Yield (tonnes/ha) two year average	
	Barley	Wheat
Soil without erosion no fertilizer	2.75	4.43
Soil with moderate erosion no fertilizer	2.06	3.38
Soil with moderate erosion plus NPK-fertilizer	2.73	4.31

Source: Kharytonov et al., 2004.

Table 18: Characteristics of annual dust storms by AEZ

Zone	Number of days	Duration hours	Wind velocity (m/s)								
			2-4	5-7	8-10	11-13	14-16	17-19	20-22	23-25	26-28
Forest	1.1	2.7	13	24	25	14	11	8	5	-	-
Forest-Steppe	1.1	2.6	15	26	22	15	9	9	4	-	-
North and Central Steppe	2.9	8.5	8	15	21	12	17	14	10	2	1
South Steppe	5.3	17.5	6	14	20	14	17	17	9	2	1

Source: Dolgilevich, 1997.

Considering a soil bulk density of 1 tonne per m^3, a loss of 10 tonnes of soil per ha corresponds to a loss of 1 mm of the top soil layer, which mostly contains C-rich soil organic matter. Taking a 5 percent content of soil carbon, a loss of 10 tonnes of soil corresponds to a loss of 0.5 tonnes of C per ha, an important figure compared with the existing potential soil C sequestration levels (See Annex 7).

A study from Kharytonov *et al.*[56] in the Dnepropetrovsk district showed that eroded soils have significantly lower humus and clay contents, and higher pH and carbonates values (Table 16). They also reported that soil macro and micro-nutrients (Manganese, Zinc, and Copper) were 30-50 percent lower in a moderately eroded plot compared with a control plot without erosion.

The authors also showed that even adding a complete and efficient fertilizer (NPK 60 kg per ha in the form of nitrophoska [N17-P17-K17] a synthetic polymer-based fertilizer) the yield is still slightly below the non-eroded soil without fertilizer.

56 Kharytonov M., Bagorka M., Gibson P.T. 2004. Erosion effects in the central steppe Chernozem soils of Ukraine. I. Soil properties. Agricultura, 3, 12-18.

Table 19: Effects of tillage levels on soil losses
(Kilograms/m²/year; Average 2011-2012)

Ploughing	6
Mini-till	4.5
No-till	3

Source: In-field personal communication (SCAI of Donetsk). May, 2013.

Wind erosion

Dolgilevich[57] studied the extent and severity of wind erosion in Ukraine using information about dust storms over a forty year period including the number, duration and the wind velocity of storms at all meteorological stations of the Ukraine. Its analysis showed that wind erosion takes place in all AEZ. The climatic parameters of wind erosion were determined as follows: The mean number of days with dust storms reaches 3-5 days in the Steppe zone and 1 day per year in the Forest zone. The duration of dust storms is 8-17 and 3 hours per year. Wind velocity during dust storms reaches 21 and 15 $m.s^{-1}$ respectively (Table 18). The author also reported that Chernozems are most susceptible to wind erosion and are severely degraded.

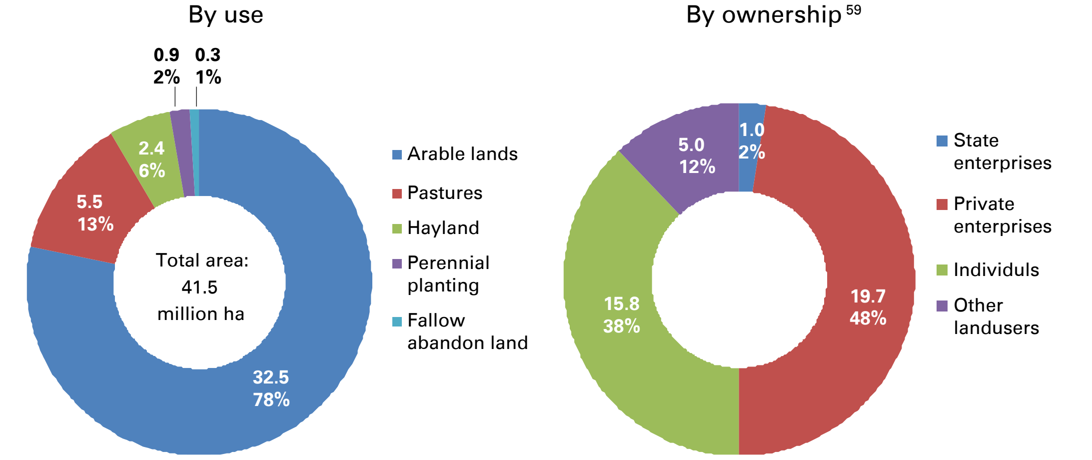
Addressing erosion

Land resource management is the best cost-effective way to address erosion. Conservation agriculture practices are often cited by farmers and soil scientists as having several positive outcomes for reducing risks from drought. These include: reducing soil erosion; enhancing moisture retention; and depending on the soil texture, minimizing soil compaction. Conservation agriculture is also credited with limiting damage from runoff and erosion during flooding. Some producers are also enhancing the establishment of shelterbelts mostly to address wind erosion. Shelterbelts also provide protection from heat and wind for livestock. Another way to address wind erosion is to maintain the soil as moist as possible. One solution in a country with important snow precipitation is to cut stubble at different heights to trap snow on field surfaces and so enhance spring moisture levels in the soil. The stubble also helps maintain the snow in place during the windy periods.

57 Dolgilevich M.J. 1997. Extent and Severity of Wind Erosion in the Ukraine. Proceeding of the workshop "Wind Erosion: An International Symposium/Workshop". http://www.weru.ksu.edu/symposium/proceedings/dolgilev.pdf.

Annex 3 - Land, cropping structure, and yields

Figure 30: Agricultural land structure in Ukraine, million ha



Source: MAFP, "Panorama of Ukraine Agrarian Sector 2012".

Table 20: Agricultural lands by ownership in 2012

	Type of ownership			Total
	Enterprises	Rural households	Others	
Units	47 652	5 100 000	-	-
Agricultural land, million ha	20.7	15.8	5.0	41.5
Arable land, million ha	19.4	11.6	1.5	32.5

Source: MAFP, Panorama of Ukraine Agrarian Sector 2012.

Role of agriculture in the national economy

With an agricultural GDP of 111.7 billion UAH[58] in 2012, agriculture contributed 7.93 percent to the Ukrainian GDP. Sixty seven percent of this was from crop production: the main agricultural sub-sector. Livestock production contributed the remaining 33 percent.

Land distribution by use, enterprise, region and agroclimatic zone

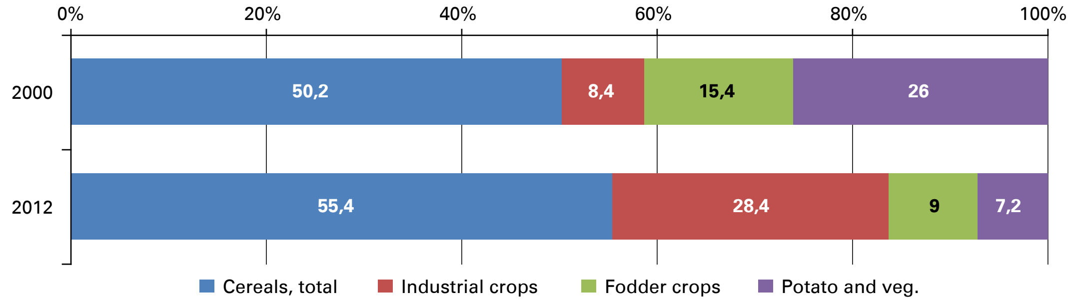
According to the most recent data provided by MAPFU, at the end of 2012, 69 percent of the entire Ukrainian territory was agricultural land (41.5 million ha). Over 78 percent of this (32.5 million ha) is arable land (see Figure 30).

As shown by Table 20, 36.5 million ha (88 percent of total agricultural land) are owned by enterprises (state and private, agricultural and farm enterprises) and rural households. By the end of 2012, about 48 000 enterprises owned 50 percent of all agricultural land and 60 percent of all Ukrainian arable land.

58 UAH (Ukrainian Hiryvnia); equal to about USD 13.7 billion.

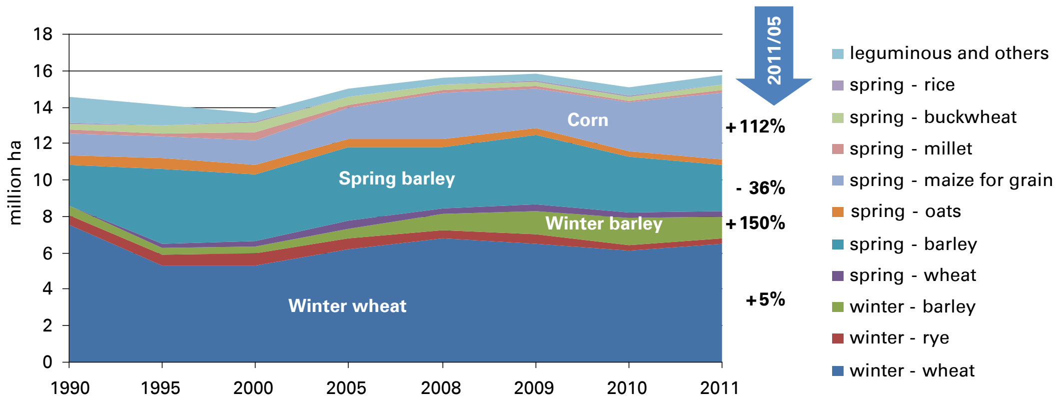
59 According to the Ukrainian State Statistics Service: An agricultural enterprise (state or private) is defined as in-dependent business entities which has legal person's right and carries out productive activity on Agriculture. The structure of private agricultural enterprises includes private farms also. Private farm is a form of private business of citizens with legal person's right, who has expressed the wish to produce commodity production, to process and sell it with purpose to gain a profit. Citizens carry out their activity on land lots, which were placed at their disposal for farming.

Figure 31: Crop land structure



Source: MAFP, Panorama of Ukraine Agrarian Sector 2012.

Figure 32: Historical trends of grains, 1990-2011



Source: UkrStat.

The regional distribution of all the land owned by enterprises and rural households in 2011 is provided below. The five regions with the largest areas of arable land are Dnipropetrovsk, Odessa, Zaporizhia, Kharkiv and Kirovograd provinces. All five regions are situated in the Steppe AEZ. The Steppe zone covers 19 million ha of Ukrainian agricultural land, the Forest-Steppe zone 16.9 million ha and the Forest zone 5.6 million ha.

Crop production

According to MAPFU, in 2012 the total crop area in Ukraine was 27.8 million ha. As shown by Figure 31, over 55 percent was dedicated to cereal[60] production.

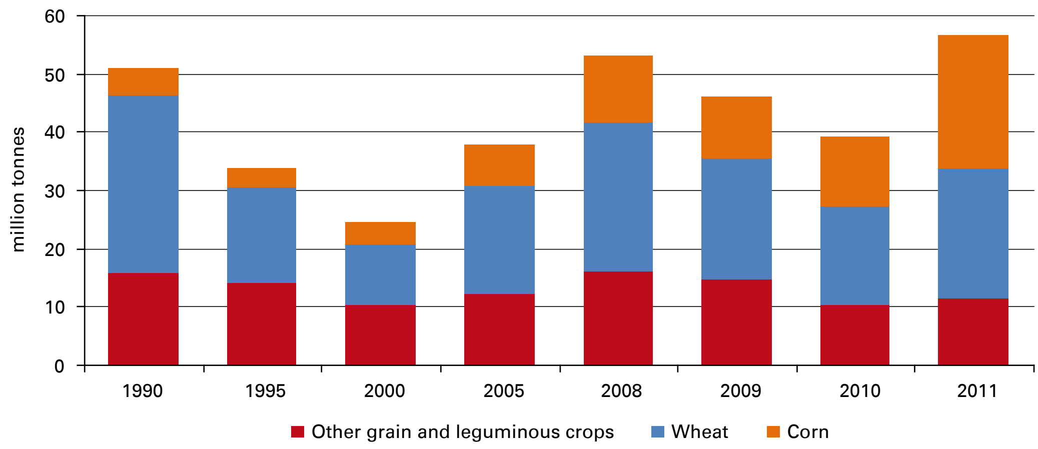
The total area under cereals has remained stable since 2007 at around 15 million ha. From 2005 to 2011, the crop structure changed significantly. If the acreage of winter wheat remained stable, the areas under spring barley decreased significantly while farmers increased the areas under winter barley and corn by 150 percent and 112 percent respectively.

Despite the stable crop area, grain output in Ukraine has been unstable due to high yield variability. In the recent years, grain production ranged from slightly less than 40 million tonnes in 2010 to over 55 million tonnes in 2011. In 2012, Ukraine reported a harvest of 46.2 million tonnes of grain crops. In the last five years (2008-12), average production in the Steppe region has been 10 million tonnes of wheat and 3 million tonnes of corn; and 8 million tonnes of wheat and 9.5 million tonnes in the Forest-Steppe region.

After the stagnation in the early 1990s, the expansion of the oilseeds area (see Figure 35) has been particularly impressive, especially the sunflower seed area. Farmers decreased the area under sugar beets because of the loss of sugar export markets.

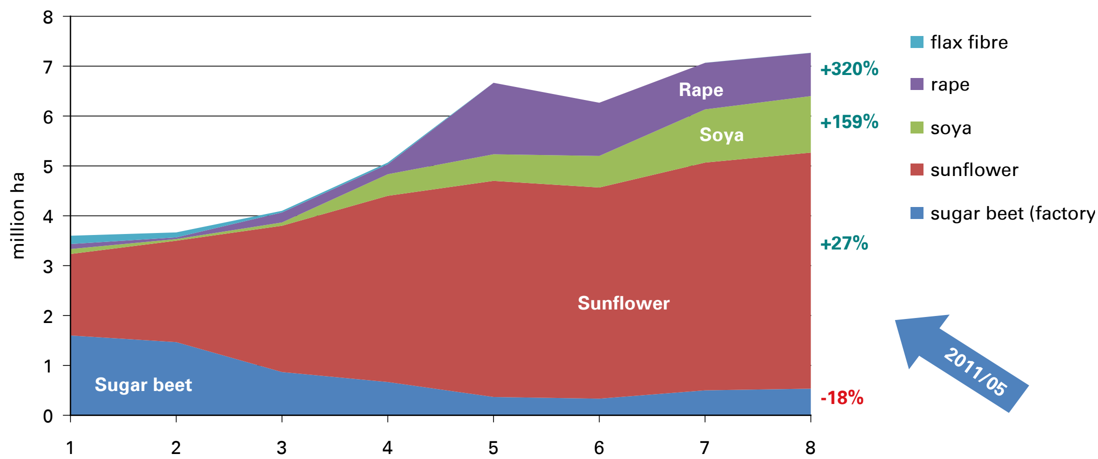
60 Wheat, barley, oats, corn, rye, minor cereals and pulses.

Figure 33: Production of main grain crops, 1990-2011



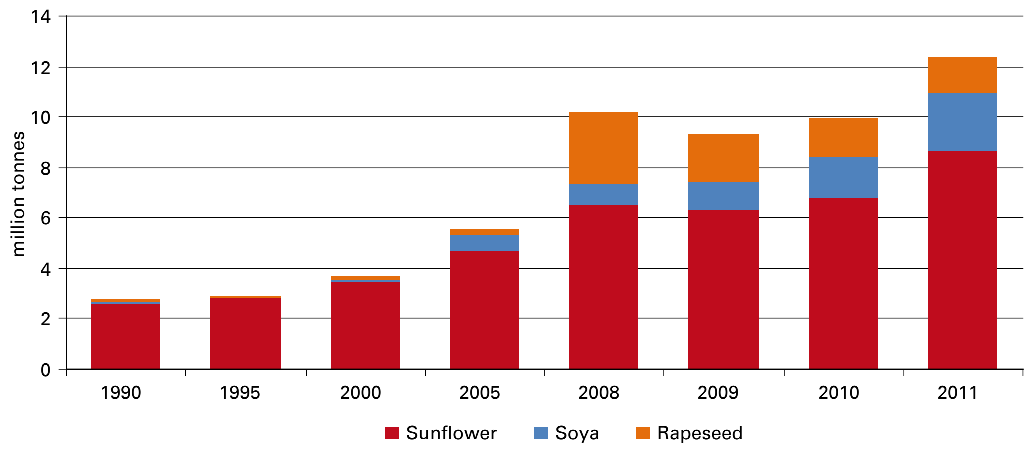
Source: UkrStat.

Figure 34: Production of industrial crops



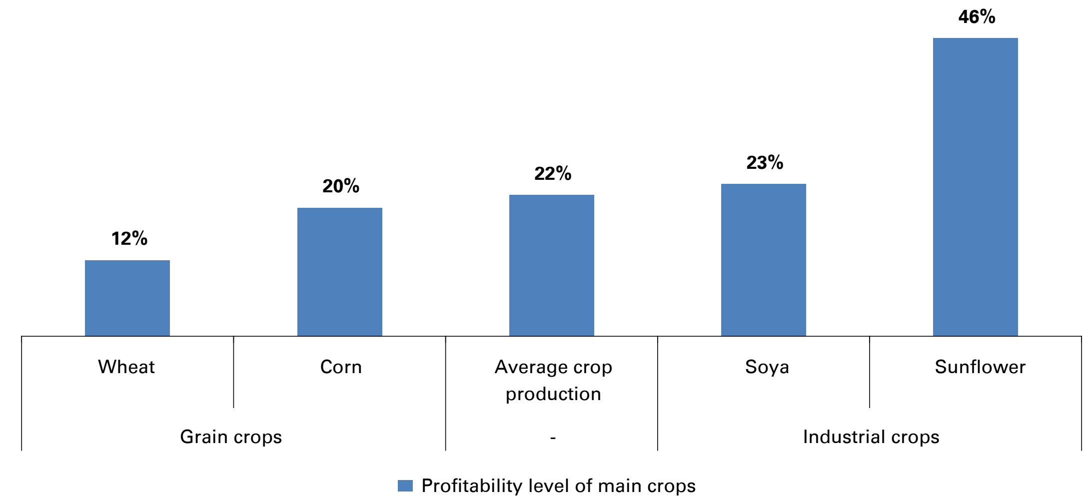
Source: UkrStat.

Figure 35: Production of main oilseed crops, 1990-2011



Source: UkrStat.

Figure 36: Profitability levels of main crops in Ukraine in 2012



Source: UkrStat.

According to MAPFU[61], agronomic sustainability of oilseed production in Ukraine requires sunflower area to decrease to 3-3.5 million ha and be in line with crop rotation recommendations provided by Resolution N 164 of 11 February 2010 (see below); areas under soya and rape seed can be considered as alternative sequences.

Compared with 2005, the output of main industrial crops more than doubled in 2011. In 2012 Ukraine produced 8.4 million tonnes of sunflower seed. In the last five years (2008-12), the average sunflower seed production in the Steppe region was 5 million tonnes, while that of the Forest-Steppe region was 2 million tonnes.

This result was a result of increasing cropped area and higher yields. In all cases, farmers' perception of the market appears to have led to their choice of a continued expansion of sunflower output. This behaviour can be explained by the fact that industrial crops (sunflower in particular) are characterized by higher levels of profitability (see official statistics in Figure 36).

Crop production: regional distribution

Crop production varies from region to region reflecting economic and agroclimatic conditions of the area. For instance, milling quality wheat is mainly produced in the Steppe and southern Forest-Steppe zones; corn dominates the Forest-Steppe zone while barley is mainly sown in the Forest and northern Forest-Steppe zones.

Yields

Potential and actual yields of crops are very different by region (corn in particular). The most productive provinces are concentrated in the central part of Ukraine – the Forest-Steppe zone. Wheat yields are rather similar across the country with Vinnytsia, Cherkasy, Khmenytskyi and Poltava provinces performing slightly better than others. Corn yields are lower in the eastern Steppe zone (Zaporizhia, Donetsk and Luhanska provinces) and are particularly high in the central Forest-Steppe zone. Sunflower performs well in the central east Forest-Steppe zone.

Yield volatility

Significant regional differences also exist in the volatility of crop yields. As visible from Table 21, lower than average wheat yield volatility was observed in Forest-Steppe and Forest zones and in Mikolaiv province. The Steppe zone is usually characterized by high volatility, particularly Kharkivska province. Corn yields were also more volatile in another Steppe zone Luhanska province. Sunflower yields were highly volatile in western regions of Ukraine but were more stable in central and south-eastern regions of the country.

High regional yield volatility has not been mitigated at national level. In the period from 2000 to

61 Ukrainian MAFP, Panorama of Ukraine Agrarian Sector 2012.

Table 21: Ukraine: volatility of yield of wheat and corn by region, tonnes per ha, 2008-2011

Agro-climatic zone	Province	Wheat				Corn			
		Min	Max	Av	StDev/Av	Min	Max	Av	StDev/Av
Steppe	Luhanska	2.4	3.8	2.8	25%	1.7	3.9	2.5	40%
	Crimea	2.1	3.3	2.6	21%	7.7	8.8	8.1	6%
	Hersonska	2.4	3.5	2.9	19%	5.2	6	5.5	6%
	Dnipropetrovska	2.9	3.8	3.2	14%	3	4.5	3.5	19%
	Zaporizka	2.6	3.5	3	13%	2.6	3.1	2.9	8%
	Kirovogradska	3	3.9	3.4	12%	4.7	6.6	5.3	16%
	Donetsk	2.9	3.6	3.2	11%	2.1	3.8	2.9	23%
	Odesska	2.6	3.3	3	11%	2.7	4.1	3.5	19%
	Mikolaïvska	2.9	3.1	3	4%	2.9	4.7	3.9	20%
Forest-Steppe	Harkivska	2.1	4.6	3.4	31%	2.6	5.7	3.9	33%
	Kyivska	2.5	4	3.2	23%	5.3	8	6.3	20%
	Sumy	2.2	3.9	3.1	23%	3.5	6.4	5	24%
	Poltavska	2.6	4.3	3.5	20%	4.4	7.9	6	24%
	Ternopilska	2.5	3.8	3.3	17%	5.3	6.3	5.6	9%
	Hmelnickiy	2.9	4.1	3.5	15%	5.3	6.3	5.9	7%
	Vinnitska	3.3	4.5	4	13%	5.5	7.5	6.3	14%
	Lvivska	2.5	3.5	3.1	13%	5.2	6.4	5.8	10%
	Cherkaska	3.5	4.7	4.2	13%	5.3	9.1	6.8	25%
Forest	Chernigivska	2.2	3.3	2.9	20%	4	6.5	5	21%
	Zhytomyrska	2.5	3.4	3.1	13%	5.1	7.2	6.4	15%
	Rivnenska	2.9	3.7	3.2	10%	4.7	5.7	5	9%
	Volinskiy	2.6	3.2	2.9	10%	6	7.1	6.3	8%
Mountains	Chernivetska	2.7	3.8	3.3	15%	4.8	5.8	5.2	9%
	Zakarpatska	2.1	3.1	2.8	16%	4.5	4.8	4.7	2%
	Ivano-Frankivska	2.5	3.7	3.1	16%	4.6	5.8	5	11%

Source: Own calculations based on 2011 UkrStat data.

2012, corn yields in Ukraine fluctuated from 3 to 6.4 tonnes/Ha with an average yield of 4.2 tonnes/ha and wheat yields from 1.5 to 3.7 tonnes/ha with an average yield of 2.8 tonnes/ha.

In order to quantitatively assess the volatility of yields we calculated their Standard Deviation. The charts below show the volatility of yields: Ukraine is among the top three countries for high yield volatility.

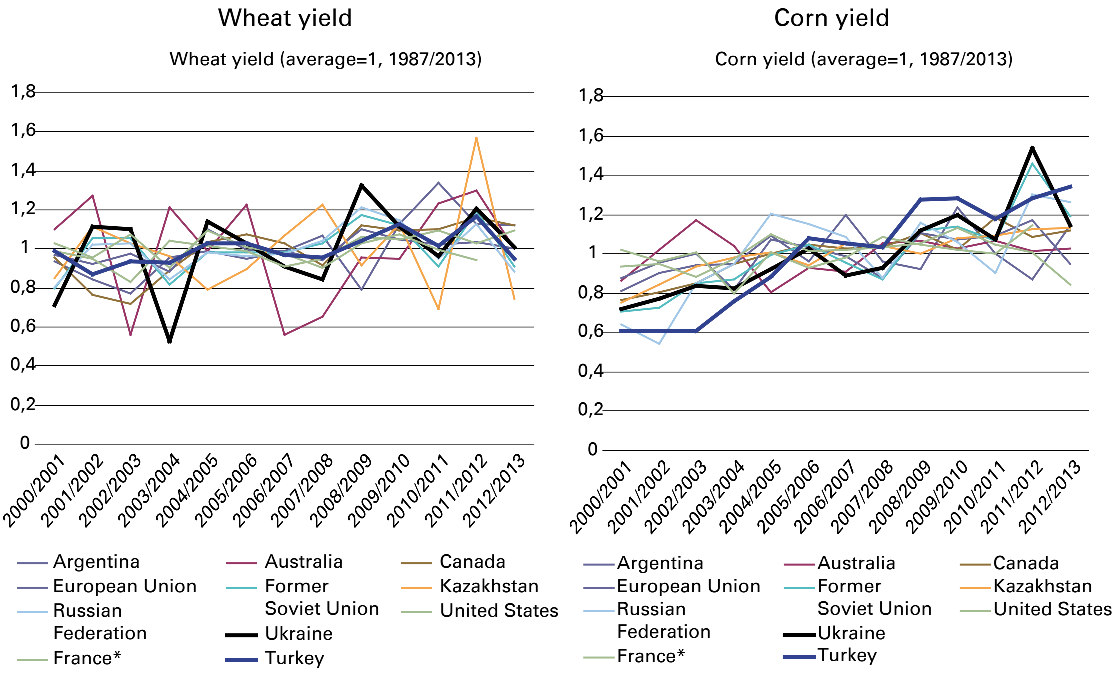
The persisting high volatility in yields of the main cereal crops in Ukraine negatively impacts national output levels. During the period from 2000 to 2012 Ukraine produced on average 9.7 million tonnes of corn and 17 million tonnes of wheat per year. In the same period, the minimum and maximum annual production levels of corn varied from 28 percent below average to 54 percent above it and wheat production varied from 48 percent below average to 30 percent above it.

Crop calendar and cropping patterns

Winter wheat, corn, sunflower and spring barley (main crops in Ukraine) are planted and harvested according to the calendar below.

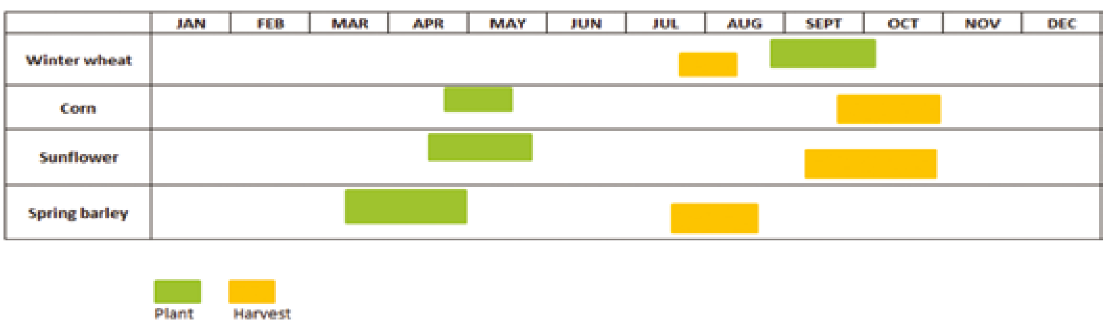
Winter wheat production is mostly concentrated in the central and south-central Ukraine, with the hard red winter wheat type the most cultivated.

Figure 37: World: volatility of wheat and corn yields (Deviation from average 1987-2012)



Source: Own calculations based on PSD USDA..

Figure 38: Ukraine: calendar of main crops



Source: USDA.

Sunflower, the principal Ukraine oilseed crop, has become one of the most profitable crops due to a combination of high price, a relatively low production cost. Unfortunately, this results in frequent violations of crop rotation schemes recommended by agricultural officials.

The official recommended frequency of sunflower in crop rotation is once every seven years because of phytosanitary conditions and the nutrient balance of soils. The one in seven years frequency is recommended for the prevention of: (i) soil-borne fungal diseases (with most farms facing financial constraints that limit their access to fungicides and disease-resistant hybrids, specialists see crop rotation as the best way - or the only way - to control disease in sunflower fields); (ii) depletion of soil fertility, for the deep rooting system that extracts higher amounts of nutrients from the soil than other crops in the rotation; (iii) depletion of soil moisture; the deeper sunflower taproot utilizes water that can otherwise constitute a reserve, considering the frequent occurrence of droughts. According to recommendations[62] sunflower should occupy the last place in the rotation prior to the fallow year, in order to restock soil moisture.

62 *Resolution of February 11, 2010 N 164 On approval of optimal ratio of crops in crop rotations in different natural and agricultural zones.*

Table 22: Crop rotation recommendations

	Structure of sown areas (in percentage)							
Natural and agricultural region	grains and legumes	Industrial crops			Potatoes, vegetables, melons	Forage crops		Fallow
	All	All	Incl.: rape	Incl.: sunflower	All	All	Incl.: grasses	
Polissya (Forest)	35-80	3-25	0,5-4	0.5	8-25	20-60	5-20	
Forest-Steppe	25-95	5-30	3-5	5-9	3-5	10-75	10-50	
Northern Steppe	45-80	10-30	10	10	Up to 20	10-60	10-16	5-14
Southern Steppe including irrigated	40-82	5-35	5-10	12-15	Up to 20	Up to 60	Up to 25	18-20
Pre-Carpathians	25-60	5-10	5-7		8-20	25-60	10-40	

Allowable frequencies of growing crops in a same field are:

- winter rye and barley, spring barley, oats, buckwheat - not less than one year;
- winter wheat, potatoes, millet - not less than two years;
- corn in the rotation or temporarily withdrawn from the rotation field - two/three years;
- perennial legume grasses, legumes (except lupine), sugar and fodder beets, winter rape and spring - not less than three years;
- flax - not less than five years;
- lupine, cabbage - not less than six years;
- sunflower - not less than seven years;
- medicinal plants (depending on the biological properties) - one to ten years.

Source: Resolution of February 11, 2010 N 164 on approval of optimal ratio of crops in crop rotations in different natural and agricultural zones.

Barley production mostly consist of spring-sown barley (approximately 90 percent of total barley production), The area sown with spring barley typically fluctuates in response to the level of winter wheat that is sown in the autumn and the amount of wheat winterkill; spring reseeding of damaged or destroyed winter crop fields is common. Malting barley production has significantly increased as a result of higher demand from the brewing industry and the import demand of high-quality planting seed from the Czech Republic, Slovakia, Germany, and France.

The sown area of maize has progressively increased, becoming the third most important grain crop. It is mainly planted in eastern and southern Ukraine, excluding some extreme southern provinces with insufficient rainfall to support its cultivation.

After the liberalization of Ukrainian agriculture, farmers cropping patterns have changed and are now more market-oriented, influenced by the profitability levels characteristic of single crops.

Based on information collected during our field visit, among the most common crop rotation schemes in the Steppe zone are the following:

- winter wheat > 2. corn (or barley) > 3. sunflower (or winter wheat) > 4. soybean (or mustard, or sorghum);
- pulses (e.g. chick pea) > 2. winter wheat > 3. sunflower > 4. sorghum (commercial crops rotation);
- alfalfa > 2. alfalfa > 3. alfalfa > 4.Corn silage > 5. winter wheat or pulses/grass in dry year (fodder crops rotation).

Despite official recommendations provided by the "Resolution of February 11, 2010 N 164 On approval of optimal ratio of crops in crop rotations in different natural and agricultural zones" (see Table 22), establishing a clear frequency of crops useful to preserve soil fertility and to better manage soil-borne diseases, the frequency of crops such as sunflower or a few grain crops in the same field has increased.

Annex 4 - Climate change in Ukraine

Main climatic features of Ukraine

Ukraine is situated on the southwest of the Eastern European plain. Almost all of Ukraine is within the temperate zone with a moderately continental climate. The southern coastal region of Crimea has sub-tropical features. The climate is generally favourable for most of the important crops and in some areas of the country two harvests are possible.

Total annual solar radiation varies from 96 to 125 kcal/cm^2. The average annual air temperature increases from 5-6°C in the northeast up to 9-11°C in the southwest. Absolute values of temperature: minimum -34 to -37°C of frost, maximum +36 to +38°C above zero.[63] On average, 300-700 mm of precipitation falls annually on flat areas. The distribution of rainfall in Ukraine shows a decrease from north and north-west to south and south-east.

The three rain zones are[64]:

- zone of sufficient rainfall, where precipitation is most important. This zone is the Ukrainian Carpathian Mountains, as well as the West and Southwest of Ukraine. In the Ukrainian Carpathians rainfall exceeds 1 000 mm per year, but in parts of the mountains it reaches 1 500 mm;
- zone of unstable rainfall. This is the south-eastern and the central part of Ukraine with annual rainfall between 500-600 mm. In this zone dry years are likely, particularly in the centre; and
- zone of the insufficient rainfall with high probability of dry years and occurrences of droughts. This includes the eastern and southern part of the country. Here precipitation is less than 400 - 500 mm per year, but near the sea coast even less than 400 mm.

63 Data from the Ukrainian Agrometereological Centre (www.meteo.gov.ua).

64 Ukrainian Committee - International Commission on Irrigation and Drainage; "Irrigation management transfer in European countries of transition", March 2005.

Figure 39 depicts the agrometeorological zones in Ukraine.

Climate change trends

The above indications on productive moisture are very relevant when looked at from a climate change perspective. According to a study of climate change impact on the forest ecosystem[65], a temperature increase is forecasted for all seasons of the year on the premise of doubled CO_2 concentration in the atmosphere. Thus, according to scenarios developed on the basis of the Canadian Climate Centre Model (CCCM) and the Goddard Institute for Space Studies (GISS) model simulations, the air temperature will increase most significantly in winter, and according to the GFDL model and United Kingdom Meteorological Office model, it will increase in the spring. According to the last two scenarios, the warming in Ukraine will increase from south to north and will be the greatest in the north, in the region of the Forest AEZ during the winter and spring seasons. Under all the scenarios, the amount of precipitation will increase, and during certain seasons this increase could exceed the current level by 20 percent. However, all studies predict increased precipitation in all areas of the country. In addition, these are not necessarily tied in a positively correlated manner with the crop cycles. Other studies[66] have noted that a temperature increase of only 1°C would result in a 160 km shift in the latitudinal borders of the natural

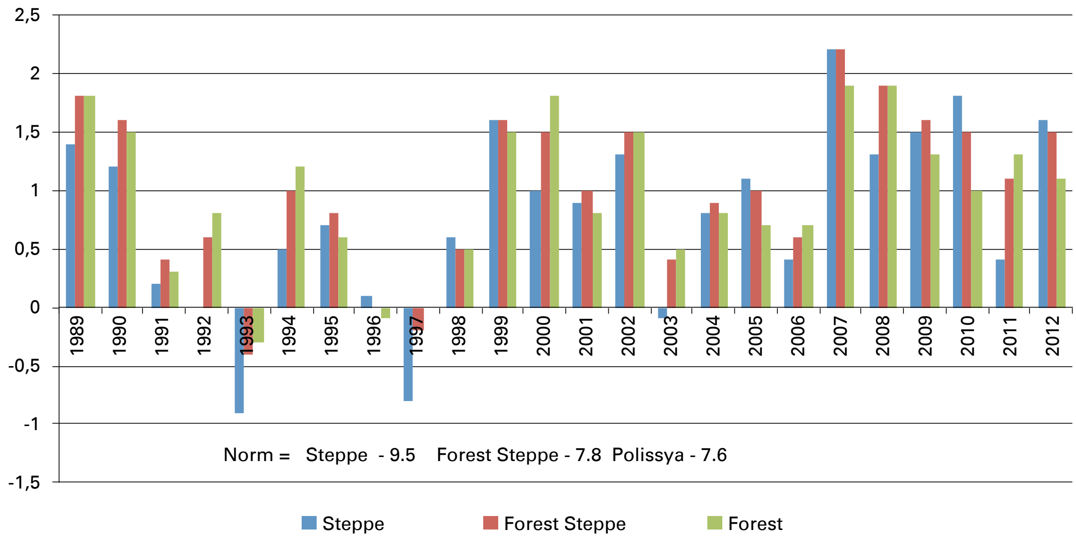
65 Igor Fedorovich Buksha. 2010: Study of climate change impact on forest ecosystems, and the development of adaptation strategies in forestry, in: Forests and Climate Change in Eastern Europe and Central Asia. Working Paper n. 8, FAO. 2010. The climate change forecast for the conditions of Ukraine was made using four models: CCCM (sensitivity to doubled atmospheric CO_2 concentration = 3.5°C), GFDL (sensitivity to doubled atmospheric CO_2 concentration = 4.0°C), GISS (sensitivity to doubled atmospheric CO_2concentration = 4.2°C), and UKMO (sensitivity to doubled atmospheric CO_2 concentration = 3.5°C).

66 Didukh, Y. 2009. Ecological Aspects of Global Climate Change: Reasons, Consequences, Actions. pp. 34-44, in: Report of the National Academy of Sciences of Ukraine, 2009, no. 2.

Figure 39: Agrometeorological map of Ukraine

Source: Adapted from Ukrainian Hydrometerological Centre.

Figure 40: Deviation from norm: average annual air temperature by AEZ (°C), 1989-2012



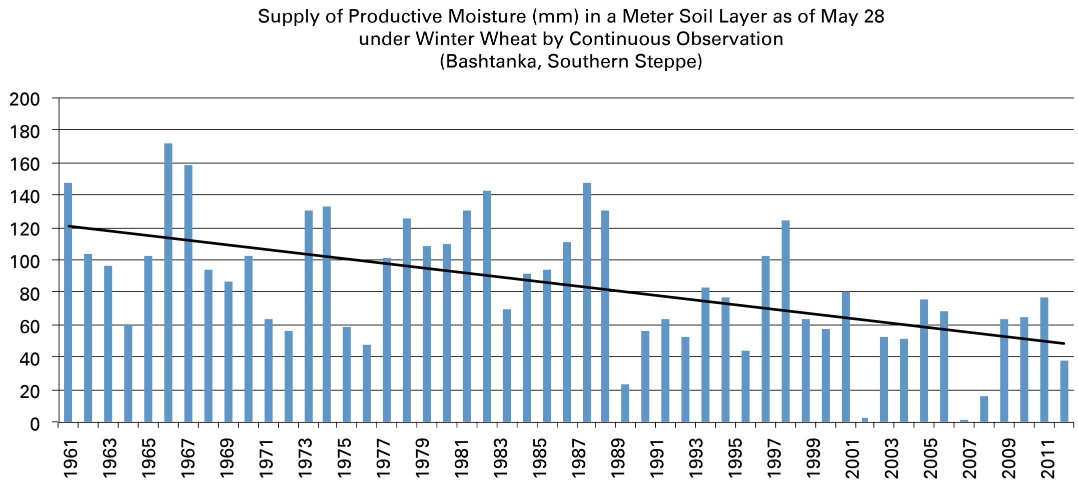
Source: Adamenko 2011.

zones; and that the temperature increase caused by warming would result in increased moisture evaporation from the soil surface. In the Forest-Steppe and Steppe zones, climate change is expected to intensify the decomposition of humus and this will result in less humus content in soils and in decreased soil fertility.

According to T.I. Adamenko, Head of Agrometeorology Department, Ukrainian Hydrometeorological Centre (UHMC), since 1989 average annual temperature in most years exceeded the norm in the Polissya/Forest and Forest-Steppe zones. These AEZ "get warmer" significantly faster than the Steppe zone. The average country level and the mean temperature deviation from the norm for various AEZ can be seen in Figure 1 and Figure 40.

The effect of higher temperatures on the reduced productive moisture appears to be more significant in the soils of the dry Steppe zone,

Figure 41: Soil moisture in AEZs, 1961-2011



Source: Adamenko 2011.

which would probably be more detrimental on crop performances in this AEZ in the future.

Scientific papers unanimously stress a considerable increase in drought areas, their frequency, intensity, duration and impact. Such tendencies are generally agreed to have taken place in the past 30 years (1980-2010) of intensive global warming and especially the last 11 years (2001-2011)[67]. Adamenko[68] has also looked at drought monitoring through satellite-based drought detection techniques[69]. Regional analysis indicate: (i) the drought area in Ukraine has not experienced any trend after 2000, although the last 50 years country average annual temperature increased by 1.45°C (twice the global increase[70]); (ii) winter temperature increase in Ukraine is higher than the summer one; (iii) total annual precipitation increased by 40 mm despite drought intensification due to a warmer climate; (iv) strong increase in winter temperature is leading to a 10 percent reduction of the winterkill area; however, reduced snow depth contributes to an increased vulnerability of winter crops during the period of sharp air temperature reduction; (v) the droughts of severe-to-exceptional and exceptional severity during the growing season normally affect 25-60 percent (up to 80 percent of the major crop area) and 5-10 percent (up to 20 percent) of the entire country and the latest is leading to up to 40 percent of losses in Ukrainian grain production every three to five years.

Crop yield dynamics

The study[71] referred to above, analyzed yield dynamics of the main cereal crops in major provinces of all regions of Ukraine during 14 years from 1996 to 2009[72]. Both winter (Wheat; Barley; Rye) and spring crops (Wheat; Barley; Oats) were examined. As a general trend, cereals show a positive yield trend in all AEZ. This increase can be attributed to a number of factors, including improved rates of mineral fertilizer application, better crop protection and plant genetics. However, it is clear that yields of all crops and in all regions vary greatly due to weather conditions. As can be seen in Figure 42, yield fluctuations in the Dnipropetrovsk area of the Steppe region are strongly marked, and during the years characterized by drought conditions (2003/2007) there is a drastic reduction of yields.

67 T.I. Adamenko, *et al*: Global and Regional Drought Dynamics in the Climate Warming Era, in International Journal of Remote Sensing, 2011.

68 *Op. cit.* in note n. 6.

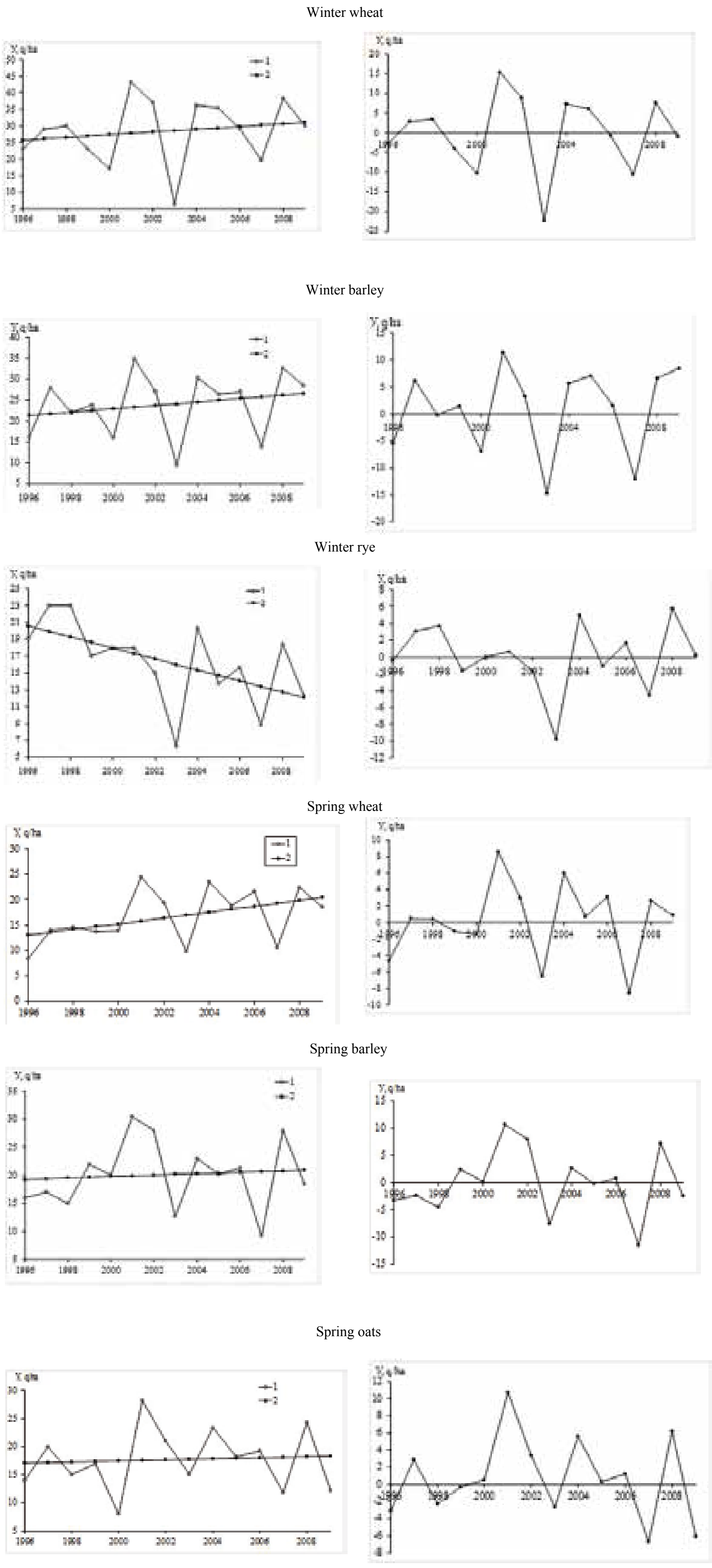
69 Using data obtained from the Advanced Very High Resolution Radiometer (AVHRR) on NOAA polar orbiting satellites. In addition, Vegetation health method is used to estimate the entire spectrum of vegetation condition or health from AVHRR-based Vegetation Health (VH) indices.

70 The latest available (4th) IPCC report stated that the average Earth surface temperature in the past 100 years increased 0.74° (Solomon *et al*, 2007).

71 See note n. 6.

72 Trend lines were calculated using harmonic weights, yield deviations from trend lines, trend productivity dynamics and assessment of climate variability of yields across territories of Ukraine.

Figure 42: Crop yield dynamics (Dnipropetrovsk, Steppe), 1996-2009



Source: Adamenko 2011.

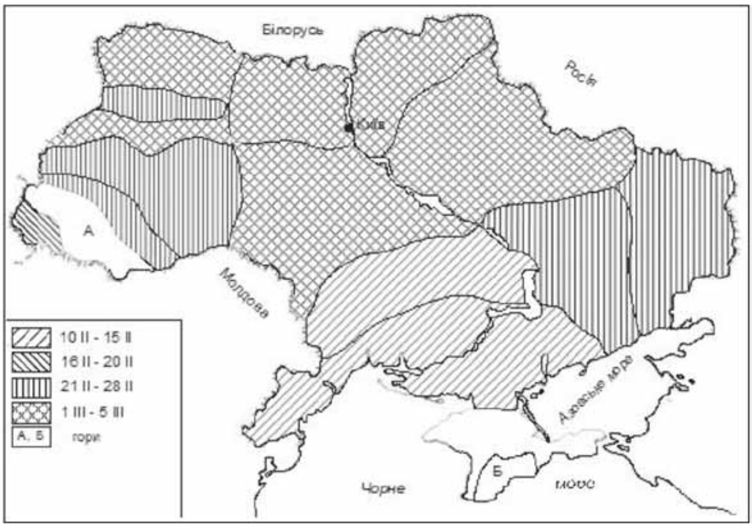
Table 23: Ukraine: yield coefficients of climate variability, 1996-2009

Soil climatic zone, Province	Winter wheat	Winter rye	Winter barley	Spring wheat	Spring barley	Oats
Polissya						
Volinskiy	0.12	0.14	0.23	0.12	0.12	0.15
Rivnenska	0.14	0.14	0.19	0.13	0.16	0.20
Zhytomyrska	0.17	0.13	0.31	0.24	0.15	0.15
Chernigivska	0.19	0.14	0.14	0.13	0.16	0.14
Forest-Steppe						
Lvivska	0.10	0.12	0.13	0.09	0.13	0.10
Ternopilska	0.18	0.19	0.26	0.15	0.14	0.15
Hmelnickiy	0.21	0.17	0.18	0.16	0.16	0.14
Vinnitska	0.22	0.17	0.20	0.21	0.17	0.15
Kyivska	0.21	0.13	0.20	0.11	0.17	0.14
Sumy	0.25	0.17	0.35	0.17	0.18	0.19
Cherkaska	0.26	0.19	0.24	0.19	0.21	0.15
Poltavska	0.31	0.17	0.29	0.21	0.21	0.16
Harkivska	0.30	0.22	0.35	0.21	0.27	0.21
Steppe						
Kirovogradska	0.32	0.24	0.30	0.36	0.31	0.26
Dnipropetrovska	0.34	0.26	0.31	0.28	0.30	0.31
Donetsk	0.28	0.21	0.30	0.30	0.27	0.22
Luhanska	0.32	0.26	0.30	0.36	0.28	0.25
Odesska	0.32	0.25	0.30	0.30	0.31	0.28
Mikolaïvska	0.33	0.27	0.36	0.36	0.32	0.31
Zaporizka	0.27	0.22	0.31	0.33	0.36	0.27
Hersonska	0.29	0.25	0.32	0.40	0.33	0.31
Crimea	0.12	0.17	0.15	0.26	0.24	0.21
Zakarpattya and Prykarpattya						
Zakarpatska	0.34	0.13	0.14	0.16	0.18	0.12
Ivano-Frankivska	0.15	0.11	0.12	0.12	0.11	0.08
Chernivetska	0.22	0.20	0.22	0.22	0.14	0.10
Across Ukraine	0.22	0.14	0.13	0.13	0.20	0.13

Note: 0.00-0.20 climate stable yields; 0.21-0.30 moderately stable yields; >0.30 unstable yields

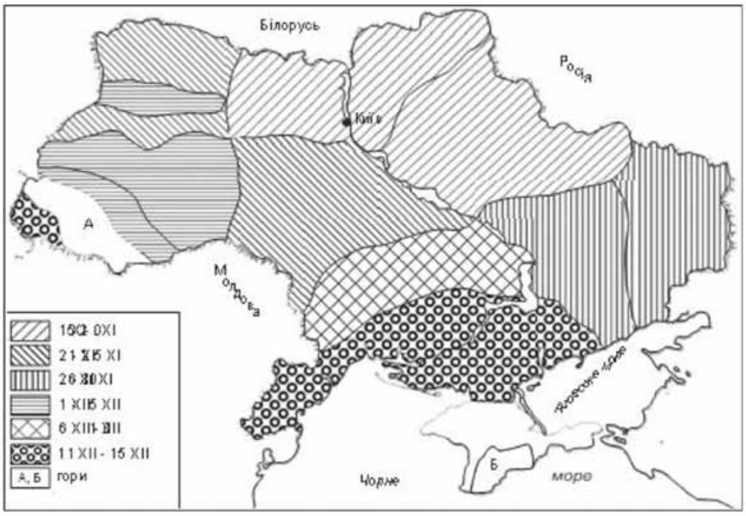
Source: Stepanenko S.M., Polovy A.M., Shkolny E.P., et al. "Assessment of climate change impact on economic sectors of Ukraine," Ekolohiya, Odessa 2011.

Figure 43: Ukraine: forecast of dates of spring season higher temperatures by zones ($>5\ ^0C$) anticipation, 2030-2040



Source: Stepanenko S.M., Polovy A.M., Shkolny E.P., et al. "Assessment of climate change impact on economic sectors of Ukraine", Ekolohiya, Odessa 2011.

Figure 44: Ukraine: forecast of autumn season higher temperatures by zone and date ($>5\ ^0C$) delay, 2030-2040



Source: Stepanenko S.M., Polovy A.M., Shkolny E.P., et al. "Assessment of climate change impact on economic sectors of Ukraine", Ekolohiya, Odessa 2011.

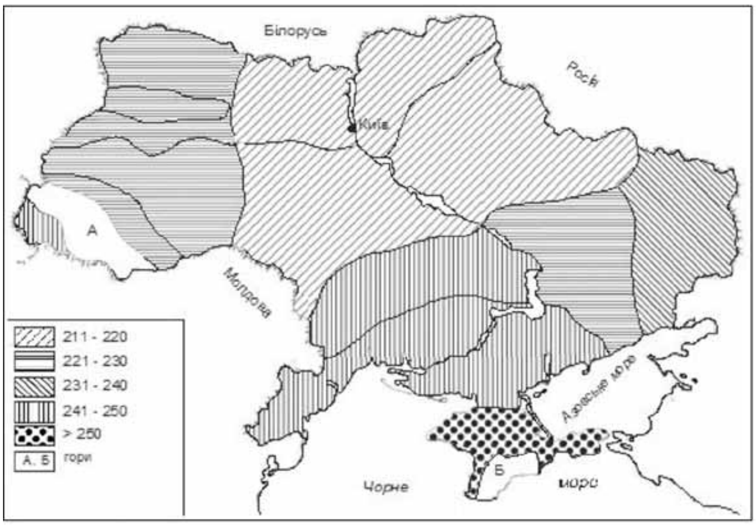
As shown in the Table 23, crops in the Steppe region are those most subjected to climate variations. Weather variations can be described by the weather coefficient of yield variability Cp, which is calculated as follows[73]:

$$C_p = \frac{1}{\bar{\bar{Y}}}\sqrt{\frac{\sum(Y_i - \bar{Y})^2 - \sum(\hat{Y}_i - \bar{Y})}{n-1}}$$

$\bar{Y}$ – Average yields $\hat{Y}_i$ – Expected yields
Y_i – Observed yields n – Number of observations

73 Stepanenko S.M., Polovy A.M., Shkolny E.P., *et al.* "Assessment of climate change impact on economic sectors of Ukraine", Ekolohiya, Odessa 2011.

Figure 45: Ukraine: forecast of temperatures (>10 ⁰C) duration by zone, 2030-2040



Source: Stepanenko S.M., Polovy A.M., Shkolny E.P., et al. "Assessment of climate change impact on economic sectors of Ukraine," Ekolohiya, Odessa 2011..

Figure 46: Ukraine: forecast of precipitation with temperatures (>5 ⁰C) by zone, mm, 2030-2040

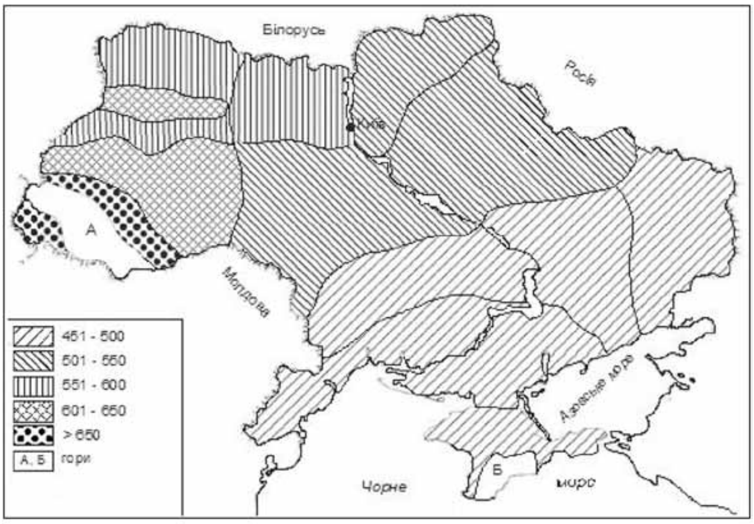
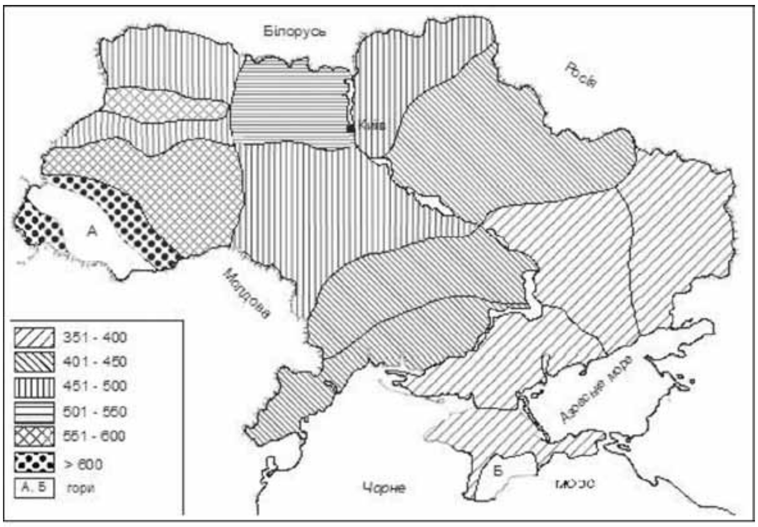
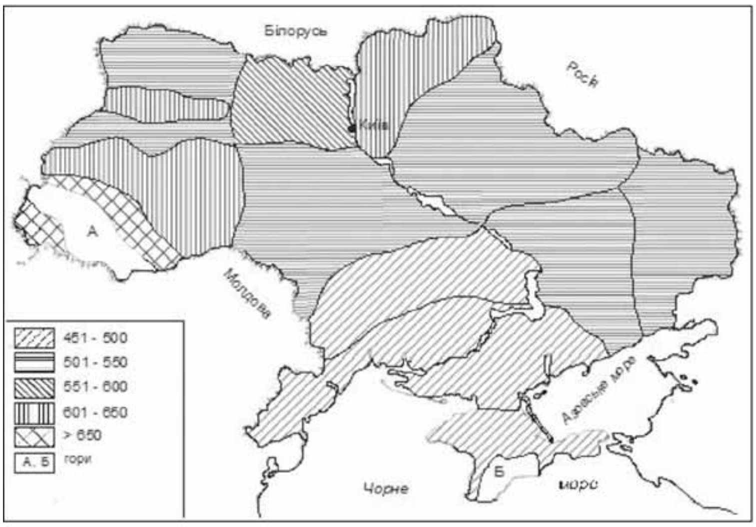


Figure 47: Ukraine: forecast of precipitation with temperatures (>10 ⁰C) by zone, mm, 2030-2040



Source: Stepanenko S.M., Polovy A.M., Shkolny E.P., et al. "Assessment of climate change impact on economic sectors of Ukraine," Ekolohiya, Odessa 2011.

Figure 48: Ukraine: evaporation scenarios by zone, mm, 2030-2040



Source: Stepanenko S.M., Polovy A.M., Shkolny E.P., et al. "Assessment of climate change impact on economic sectors of Ukraine," Ekolohiya, Odessa 2011.

Forecasts 2030-2040

Regarding climate change scenarios in 2030-2040, Adamenko *et al*[74, 75]confirm the findings of Bukhsa[76] (except that the latter reports a precipitation decrease of 180 mm in some localities in the south of the country). The Adamenko study also discusses about anticipation by 30-33 days of spring air temperatures above 50° Cin Forest, Forest-Steppe and northern Steppe AEZs; and by 39-41 days in the southern Steppe.

Autumn temperature transition in the years 2030-2040 will come later and will be delayed until the 13th-15th of December in the South, and until the 20th-25th of November in Forest/Polissya region (a 23 day delay in Polissya and a 30 day delay in southern Steppe).

The changes in duration of the period with the temperatures above 10 °C are more substantial (in periods that are relevant to active vegetation of agricultural crops): the period increases to 215 days in central Polissya; and to 250 days in Southern Steppe.

74 Stepanenko S.M., Polovy A.M., Shkolny E.P., *et al.* "Assessment of climate change impact on economic sectors of Ukraine", Ekolohiya, Odessa 2011.

75 Using Geophysics Fluid Dynamics Laboratory (GFDL) model at 30% increase of GHG emissions.

76 See note n. 3.

With respect to precipitation, for the period with the temperatures above 5 and 10 °C, it will be higher than that of 1991 to 2005. Comparison of this previous period with deviations by 2030-2040 has shown that for all seasons the amount will increase, except in autumn.

Total evaporation will increase. The lowest increase will be in western Polissya – by 10 mm (but in between the two previous observation periods [1961-1990 and 1990-2005] it had already increased by 22 mm). The highest evaporation will occur in eastern Polissya - up to 100 mm, in Western Forest-Steppe and in Southern Steppe up to 80-90 mm. In Ukraine evaporation will range from 615 mm in eastern Polissya to 470 mm in Southern Steppe.

Crop scenarios

The forecast for the 2030-2040 crop climate change scenario is based on a GFDL-30% model[77]. Simulations provide the region-specific agroclimatic indicators for the winter wheat

77 The Geophysical Fluid Dynamics Laboratory (GFDL) is a laboratory in the National Oceanic and Atmospheric Administration (NOAA)/Office of Oceanic and Atmospheric Research (OAR). GFDL's accomplishments include the development of the first climate models to study global warming, the first comprehensive ocean prediction codes, and the first dynamical models with significant skill in hurricane track and intensity predictions. Much current research within the laboratory is focused around the development of Earth System Models for assessment of natural and human-induced climate change. A 30 percent model is one that assumes GHG emissions at that level.

crop (compared with long-term data) shown in Table 24. To summarize, the scenario is characterized by higher temperatures at all stages and in particular much warmer at wintering stage (mitigating winterkill effects), and slightly increased precipitation at sowing stage but substantially reduced rainfall during wintering.

As a result, Table 25 shows the main climate change adaptation phenological behaviour for winter wheat. Compared with long-term data, it is foreseen that the following conditions will occur:

- delayed sowing dates (by 20-25 days);
- anticipated vegetation recovery after winter dormancy period;
- crop ripeness is proportionally delayed; and
- overall plant cycle length is substantially unchanged.

In terms of crop yield performance, the growth trend reported for the 1996-2009 period appears to be confirmed in the 2030-2040 scenario simulation. It would appear that mitigation of winterkill due to higher winter temperatures, improved moisture supply at vegetation recovery stages, and diminished moisture deficiency conditions are able to produce increased yields. Surprisingly, the best performances would be in the Steppe area.

Unfortunately, the scenarios analyzed in the referred study are silent on crop yield dynamics as well as on precipitation and moisture supply dynamics. However, since all climate change studies tend to agree that variability of climatic conditions and frequency of extreme events will also increase, it may be assumed that – in a best case scenario - a similar pattern to that examined for the 1996-2009 period may also occur in the future (see Figures 40-42).

It is worth mentioning the findings of a previous study[78], which observed the longest data set of soil moisture available in the world: 45 years (1958-2002) of gravimetrically observed plant available soil moisture data for the top 1 m of soil, observed every 10 days during April-October for 141 stations from fields with either winter or spring cereals in Ukraine. The observations show a positive soil moisture trend for the entire period of observation but with the trend levelling off in the last two decades. Five global climate models were used which all show a descending trend starting from 2000, but differing one from the other: from a rough sketch (GFDL) to a decisively marked Center for Climate System Research model (CCSR) lowering trend of soil moisture.

Finally, a study done by UHMC, the Odessa State Environmental University and the Moscow Main Aviation Meteorological Centre, acknowledged that extreme conditions in precipitation have been observed in Ukraine during the last 30 years and that the number of abnormally dry and hot years, dry summers and winters have increased in some regions. Accordingly, the study determines spatiotemporal features of droughts in Ukraine during the last 60 years by using the Standardized Precipitation Index showing that there is an increasing trend in droughts in the southern regions during the whole 60 year period. This trend is more pronounced starting from the second half of the 1990s.

It is worth confirming that climatic simulations differ widely depending on the global model being used. The 4th IPPC report clearly depicts such wide variations as can be noted from the projection below.

78 Alan Robock, Mingquan Mu, Konstantin Vinnikov, Iryna V. Trofimova, and Tatyjana I. Adamenko: Forty Five Years of Observed Soil Moisture in the Ukraine: No Summer Desiccation (Yet); 2004, in *Geophysical Research Letters*.

Table 24: Agroclimatic conditions for winter wheat cultivation
(Numerator – by scenario GFDL model 30 %, Denominator – average long-term data)

AEZ, province	Sowing stage		Wintering stage		
	average air temperature, °C	sum of precipitation, mm	sum of sub-zero temperatures, °C	average temperature of the most cold decade, °C	sum of precipitation, mm
Polissya	10.8	97	0	0.4	122
Zhytomyrska	8.8	87	445	-6.8	211
Forest-steppe	11.7	82	0	0.4	151
Cherkaska	9.2	71	440	-6.5	198
Northern Steppe	8.4	84	0	1.5	123
Dnipropetrovska	9.2	66	415	-6.4	200
Southern Steppe	7.1	93	0	3.5	53
Hersonska	8.6	65	195	-4.0	182
Prykarpattya	9.7	83	0	1.8	95
Ivano-Frankivska	9.0	92	335	-5.9	190

Source: Stepanenko S.M., Polovy A.M., Shkolny E.P., et al. "Assessment of climate change impact on economic sectors of Ukraine," Ekolohiya, Odessa 2011.

Table 25: Development stages of winter wheat in autumn
(Numerator – by scenario GFDL-30 % model, Denominator – average long-term data)

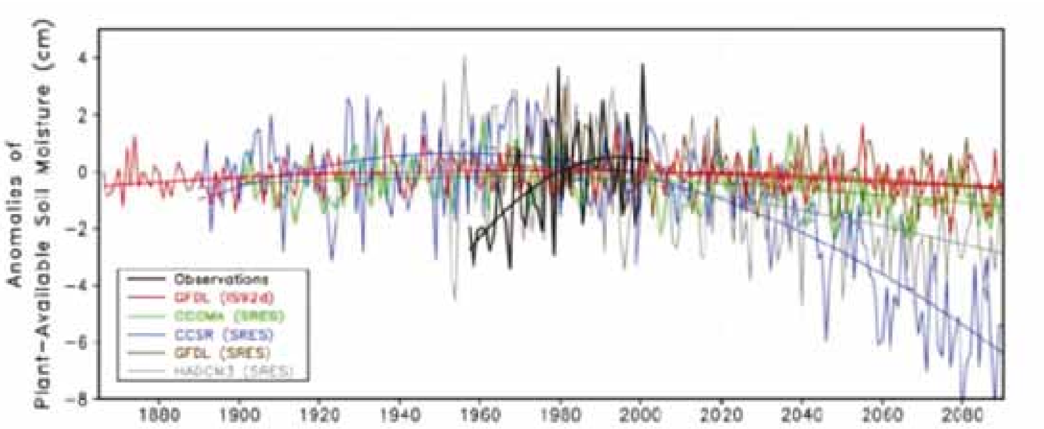
AEZ, province	Sowing	Idle vegetation	Recovery vegetation	Wax/ ripeness	Duration spring-summer
Zhytomyrska	28.09	30.11	1.03	9.06	101
Polissya	6.09	7.11	31.03	13.07	105
Cherkaska	29.09	30.11	28.02	6.06	99
Forest-steppe	9.09	8.11	29.03	7.07	101
Dnipropetrovska	13.10	13.12	25.02	1.06	97
Northern Steppe	11.09	12.11	27.03	2.07	98
Hersonska	1.11	5.01	20.02	23.05	93
Southern Steppe	19.09	25.11	21.03	26.06	98
Prykarpattya	23.10	22.12	23.02	13.06	111
Ivano-Frankivska	9.09	11.11	29.03	20.07	114

Source: Stepanenko S.M., Polovy A.M., Shkolny E.P., et al. "Assessment of climate change impact on economic sectors of Ukraine," Ekolohiya, Odessa 2011.

Table 26: Agroclimatic conditions of winter wheat in spring-summer
(Numerator – by scenario GEDL-30 % model, Denominator – average long-term data)

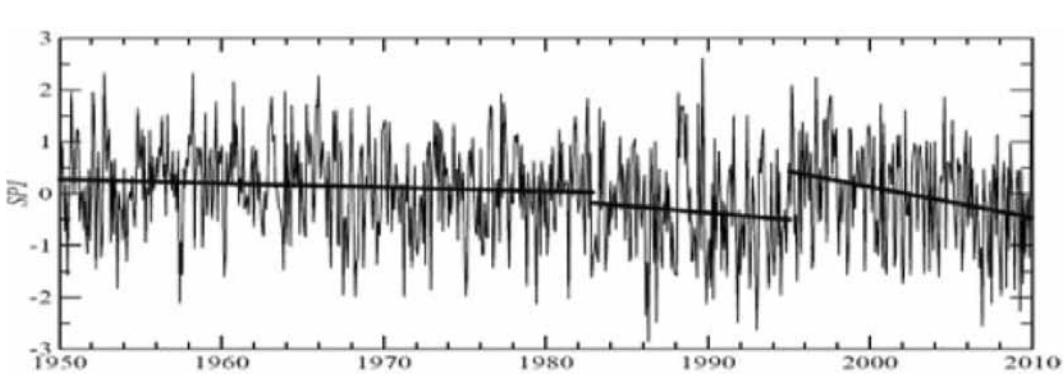
AEZ, province	rain in mm	average air temperature for period, °C		average soil moisture supply (0-100 cm), mm		Sum of solar radiation kcal/ cm²	Sum evaporation mm	Moisture deficiency mm
		Vegetation recovery	Earing-wax -ripeness	Vegetation recovery	Earing-wax -ripeness			
Polissya	196	11.1	17.4	238	166	18.8	268	90
Zhytomyrska	260	13.2	17.1	207	166	21.8	312	64
Forest-steppe	172	11.2	18.3	165	96	20.0	236	34
Cherkaska	189	12.9	18.1	146	123	21.2	252	52
Northern Steppe	151	13.0	18.5	132	77	18.3	217	35
Dnipropetrovska	147	13.3	18.7	111	90	20.5	220	101
Southern Steppe	111	11.5	17.1	122	64	17.3	173	81
Hersonska	114	13.3	19.4	87	51	21.6	192	175
Prykarpattya	346	11.5	16.2	232	209	20.9	318	191
Ivano-Frankivska	444	12.3	17.1	251	236	24.1	428	212

Figure 49: Ukraine: soil moisture compared with 1971-2000 mean



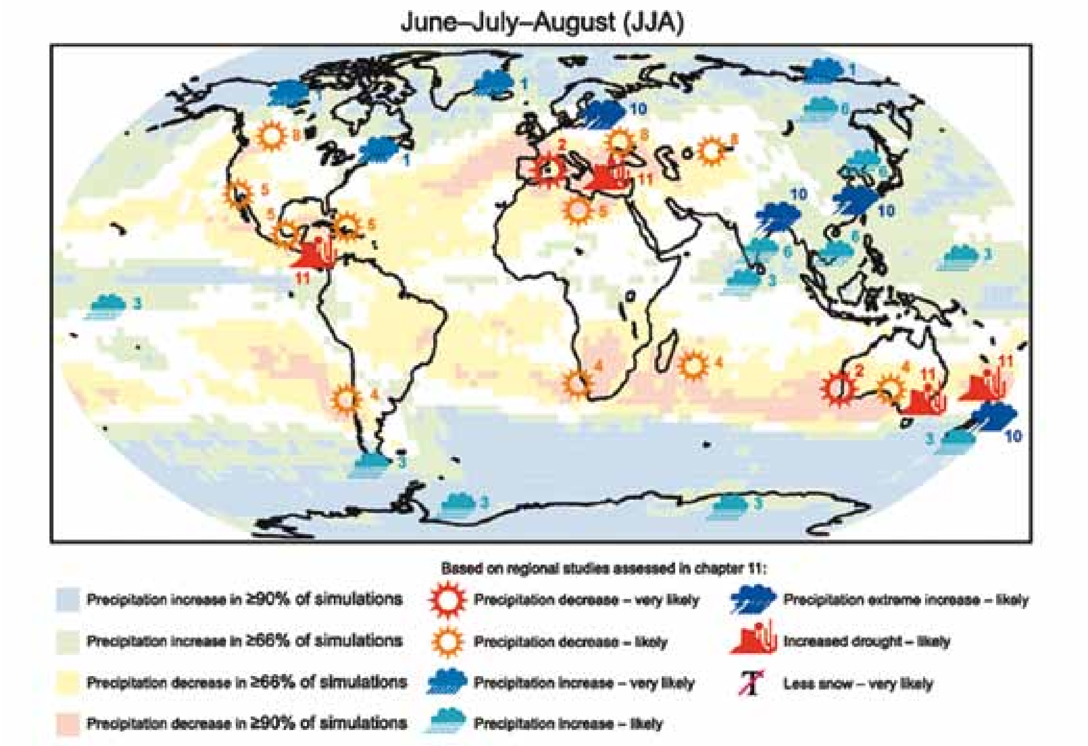
Source: Forty-five years of observed soil moisture in the Ukraine. Robok et al. (incl. Adamenko), in GEOPHYSICAL RESEARCH LETTERS, VOL. 32, LXXXXX, 2005.

Figure 50: SPI for southern Ukraine for 1950-2009 and trends for some periods



Source: Valeriy Khokhlov, Natalia Yermolenko, and Andrey Ivanov: Spatiotemporal features of droughts in Ukraine under climate change, presented during a Workshop on the Development of an Experimental Global Drought Information System, 11-13 April 2012, Frascati (Rm) - Italy.

Figure 51: Regional climate projections



Source: IPPC, 4th Report.

Annex 5 - Resource-saving technologies in Ukraine

Definitions of land preparation technologies in Ukraine

Scientists and stakeholders describe the following technologies as those in use[79] in Ukraine:

- combined tillage
- mini/minimal tillage
- zero tillage

Combined tillage is defined as applying a plough or a chisel, and at times both in succession, turning (plough) or not (chisel) the topsoil. Depending on region and cultivated agricultural crop, the technology differentiates by depth, number of operations, and set of tools. It allows deep fertilization, mechanical weed control, and incorporation of rain water before harrowing. It increases loss of SOM, it facilitates compaction, and it is a high-fuel consuming technology.

Minimum tillage is when direct seeding and a reduced number of pre-sowing/weed removing tillage operations are also practiced. The technology in Ukraine entails a number of tillage operations each season with wide (shoe type) blades or with knife tillers that cut the roots of weeds. This disturbs the soil, although less than traditional ploughing. It has a beneficial effect on erosion and reduces land preparation costs.

Zero/no-till is not specifically defined in Ukraine as it has not been studied much. The FAO definition is adopted.

The SSAcI has made an attempt to provide an indication on area/soil type technology suitability across the country. This is based on presumed soil type behaviour taking account of the known soil physical features, but however, with little empirical evidence.

The prevailing concerns of scientists in Ukraine over CA/no-till technology include the following: Soil-related (hard, sandy, stony, over moisturized, gleyish); climate-related (cold moist spring delaying nitrification processes and causing nitrogen deficit); technical (excess of weeds, rodents, and pests/diseases); organizational (need to invest in specialized machinery and related technical assistance, financial constraints and overuse/ management of herbicides and agrochemicals). It is understood – as discussed with the scientists in Ukraine – that these concerns can be all addressed through experiential learning on soil- and farm-specific cases. As a result, Table 27 would need to be revised.

Trials[80] made on yield[81] comparisons show contradictory though not disappointing results, comparing traditional (and combined), minimum-till and no-till technologies. Admittedly, it must

Table 27: Ukraine: technology suitability by AEZ, million ha

	Minimum tillage	No-till
Forest (Turf-podzolic; Turf and meadow)	2	-
Forest Steppe (black soils typical and podzolic; Dark grey; Grey and light grey)	3.4	3.5
Steppe (Black soils ordinary)	3.5	2

Source: SSAI, O.N. Sokolovsky.

79 Presentation by SSAI Sokolvsky researcher S.A. Balyuk during FAO-WB Round Table discussions in Kyiv on 23 May, 2013.

80 Presentation made by Professor S.A. Balyuk during Round Table discussions in Kyiv on 23 May, 2013.

81 According to SSAcI data, the fertility agropotential of all Ukrainian soils in the different agro-ecologies of the country is certainly high for winter wheat: 31.2-39.2 q/ha (forest); 38-64 q/ha (forest steppe); and 22-40q/ha (steppe).

Table 28: Ukraine: prevailing land/seed bed preparation technologies, million ha of cropped land, 1990-2009

Technology	1990	2000	2005	2009	Percent of total
Traditional/ploughing	29.5	19.5	10.0	4.9	18
Mini/minimum tillage	2.0	7.5	17.0	21.9	80
No-till	0	0.2	0.5	0.70	2
Total	**31.5**	**27.2**	**27.5**	**27.5**	**100**

Source: Authors' elaboration; and Agrosoyuz, 2013.[82]

be said that the no-till technology is applied improperly. In fact, depending on which crop is included in the rotation (e.g. beetroot) even the no-till soil is ploughed for that crop. This one operation cancels all the gains the technology was re-establishing on that given soil. In terms of soil humus content (SOM) - calculated while comparing the three technologies on soils which had a high SOM starting point (above 4 percent) – gains were marginal but evident at the first ten (0-10 cm) and first 20 centimetres of the soil. Otherwise at -20 cm and at 20-30 cm, very slight decreases (0.02 and 0.14 percent) were recorded. In this regard, an interesting trial which is being conducted by SSAcI on the chlorophyll content of crop leaves for the three technologies shows that no-till plants are apparently better able to produce it (Table 5).

All such trials would however need to be repeated extensively and at different locations and conditions – in full respect of each technology's correct protocol – and be documented to have a formal scientific recognition.

Prevailing situation in Ukraine

Official statistics do not mention the actual area-coverage of different land preparation technologies in the country. However, interesting assessments are made by practitioners and mainly by agricultural machinery suppliers who have their own countrywide networks and observatories. Accordingly, the evolution of land/seed bed preparation technologies in use in Ukraine is estimated to be as shown in Table 28, which shows that:

- resource-saving technologies have picked up steadily since independence and with a strong impetus during the last 15 years;
- mini-till is currently the most popular land preparation technology in use;
- traditional land preparation through ploughing has strongly decreased with an apparent trend towards being definitely substituted;
- no-till was introduced in the late nineties and has progressed slowly; and
- overall cultivated area has decreased substantially since pre-independence levels because of a combination of two main reasons: decreased access to financing needed for agricultural inputs and machinery purchases and exclusion of marginally profitable land from production.

The trends observed above are similar to those in many other FSU countries. Most of these countries in their move towards a post-FSU agricultural modernization have also had to face challenging issues such as growing erosion, decreasing soil fertility, and soil moisture impoverishment as a result of an inadequate land resource management and an increased frequency of drought events. Depending on the agro-ecological and global economic situation of each country, these challenges have had diverse impact and level of priority.

In Ukraine, given the prevalence of its richer black Chernozem soils (which by nature have higher SOM content and have more resilient chemical-physical behaviours), soil scientists and farmers appear to have prioritized two such challenges - fighting against erosion and improving farm profitability by reducing fuel consumption. Probably for these reasons, farmers have given precedence to the easier - in terms of adaptation

82 Personal communication and presentation made by representatives of the JSC AgroSoyuz in Dnepropetrovsk on March 13, 2013.

Table 29: Ukraine: technology comparison effect on soil losses
(in kg/m2; average 2011-2012)

Ploughing	6
Mini-till	4.5
No-till	3

Source: In-field personal communication (SCAI of Donetsk). May, 2013.

Table 30: Ukraine: technology comparison effect on fuel consumption
(litres/ha)

Ploughing	90-120
Mini-till	60-80
No-till	25-40

Source: Farm managers; Researchers. 2013.

requirements - minimum tillage as compared with the more complex conservation agriculture/no-till technology. The MAPFU which provides general guidance, has issued its own strategy paper to facilitate the adoption of resource-saving techniques and technologies in Ukraine[83].

It is worth noting that the introduction of no-till methods in the late 1990s was triggered by technical assistance programmes, such as the Agribusiness Partnership (AP) Program and the Food Systems Restructuring Program (FSRP), supported by the United States Agency for International Aid[84] in partnership with private agribusiness companies.

The conversion of a number of farms to a no-till or a minimum tillage system was promoted.

- In Donetsk province in 1996, the FSRP introduced reduced tillage practices in 420 private farms covering more than 300 000 hectares, and a year after the programme was expanded to other 460 farms for a land coverage of around 420 000 hectares.
- In Dnepropetrovsk province, through the AP programme; technical assistance for the introduction of reduced tillage practices was implemented for 250 farms with a total of 200 000 hectares of land.
- In three other provinces including Sumy, through the Global Agricultural Management Enterprises project (included in the AP Programme) giving technical assistance to 30-40 000 hectares.

Erosion affects, with diverse intensities, over 40 percent of arable land (see Annex 3). Indeed experimental trials have shown that the mitigating effect of "reduced tillage" technologies over erosion is immediately considerable.

Moreover, CA/no-till while it contributes to the gradual regeneration of the inherent soil structure features, also improves its "anti"- erosion impact which overtime may go beyond the levels indicated above.

From the cost of production savings standpoint, and particularly in terms of fuel consumption both research trials as well as farm management experiences in Ukraine all show and agree that ploughing is by far the highest fuel consuming technology. This is greatly reduced when moving to minimum tillage, and is further reduced with no-till.

The above indications suggest that CA/no-till technology allows farmers to better preserve soil fertility and reduce production costs compared with minimum tillage. This, together with a number of other beneficial effects (on crop yields, carbon sequestration, increase in SOM, and improved soil moisture content, all discussed elsewhere in this study) should justify a gradual but more decisive move towards adoption of this technology in Ukraine. The reasons for the rather

83 Agriculture State programme till 2015; September 19, 2007, N. 1158 ((http://minagro.gov.ua/apk?nid=2976).

84 Agribusiness Partnership Program- "The impact of CNFA (Citizens Network for Foreign Affairs) partnership in Ukraine agricultural sector ", December 31, 1997 (http://pdf.usaid.gov/pdf_docs/PNACG280.pdf.

sluggish adoption of CA/no-till in the country can be explained with the following arguments.

As previously discussed, the main areas of interest from the farmers' point of view (erosion and fuel consumption), and least for the short to medium-term, have been addressed by the minimum tillage technology to an extent which is considered quite adequate at current scientific/technical knowledge and investment/organizational capacity levels.

Farmers in Ukraine do not have sufficient evidence from the existing research and knowledge generation base on both the incremental and more sustainable benefits that can accrue by adopting CA on their farms, as well as on the appropriate measures that need to be used at different soil-climate-cropping pattern. The experience and evidence accumulated by the few big farms that have adopted CA technology are too sparse and are not always comparable; at times they are not consistent or data has not been collected with scientific rigor; and, in simple words, are thus not convincing to the broader audience. In turn, scientists have insufficient means, outdated fundamental information (e.g. on the actual status of their soils), and have had little to no exposure to international research networks working in this technology area.

Indeed CA/no-till is a long-term undertaking which is able to show its sustained benefits only overtime. The more these incremental benefits are marginal as compared with a rather acceptable starting point (soil quality, SOM, crop yields, etc.), the more the investors will be sceptical in appreciating the actual advantages.

Nevertheless, the interactions that took place during this study with the most concerned stakeholders - the farmers - confirm that there is a growing professional interest in CA/no-till. Ukrainian farmers do not appear to be entrenched in a non-critical, agnostic attitude and are eager to learn more about what the technology can actually provide in terms of benefits to them. Similarly with Ukrainian researchers in soil and other related sciences. They are ready and willing to invest more time and effort to understand how the technology can be best adapted for the different agro-ecological conditions and farms.

FAO definition of CA/no-till

According to FAO (http://www.fao.org/ag/ca/), CA is an approach to managing agro-ecosystems for improved and sustained productivity, increased profits and food security while preserving and enhancing the resource base and the environment. CA is characterized by three linked principles, namely:

- continuous minimum mechanical soil disturbance;
- permanent organic soil cover; and
- diversification of crop species grown in sequences and/or associations.

CA principles are universally applicable to all agricultural landscapes and land uses with locally adapted practices. CA enhances biodiversity and natural biological processes above and below the ground surface. Soil interventions such as mechanical soil disturbance are reduced to an absolute minimum or avoided, and external inputs such as agrochemicals and plant nutrients of mineral or organic origin are applied optimally and in ways and quantities that do not interfere with, or disrupt, the biological processes.

CA facilitates good agronomy, such as timely operations, and improves overall land husbandry for rainfed and irrigated production. Complemented by other known good practices, including the use of good quality seeds, and integrated pest, nutrient, weed and water management, CA is a base for sustainable agricultural production intensification. It opens increased options for integration of production sectors, such as crop-livestock integration and the integration of trees and pastures into agricultural landscapes.

There are the three principles of conservation agriculture.

Direct planting of crop seeds, involving growing crops without mechanical seedbed preparation and with minimal soil disturbance since the harvest of the previous crop

The term direct seeding is understood in CA systems as synonymous with no-till farming, zero tillage, no-tillage, direct drilling, etc. Planting refers to the precise placing of large seeds (maize and beans for example); whereas seeding usually refers to a continuous flow of seed as in the case of small cereals (e.g. wheat and barley). The equipment penetrates the soil cover, opens a seeding slot and places the seed into that slot. The size of the seed slot and the associated movement of soil are to be kept to the absolute minimum possible. Ideally the seed slot is completely covered by mulch after seeding and no loose soil should be visible on the surface. Land preparation for seeding or planting under no-tillage involves slashing or rolling the weeds, previous crop residues or cover crops; or spraying herbicides for weed control, and seeding directly through the mulch. Crop residues are retained either completely or in a suitable amount to guarantee complete soil cover, and fertilizer and other inputs are either spread on the soil surface or applied during seeding.

Permanent soil cover, especially by crop residues and cover crops

A permanent soil cover is important to protect the soil against the negative effects of exposure to rain and sun; to provide the micro and macro organisms in the soil with a constant supply of "food"; and alter the microclimate in the soil for optimal growth and development of soil organisms, including plant roots. The effects of a permanent soil cover include:

- improved infiltration and retention of soil moisture resulting in less severe, less prolonged crop water stress and increased availability of plant nutrients;
- source of food and habitat for diverse soil life: creation of channels for air and water, biological tillage and substrate for biological activity through the recycling of organic matter and plant nutrients;
- increased humus formation;
- reduction of impact of rain drops on soil surface resulting in reduced crusting and surface sealing;
- consequential reduction of runoff and erosion;
- soil regeneration is higher than soil degradation;
- mitigation of temperature variations on and in the soil; and
- better conditions for the development of roots and seedling growth.

Crop diversity

The rotation of crops is not only necessary to offer a diverse "diet" to the soil micro-organisms, but as they root at different soil depths, they are capable of exploring different soil layers for nutrients. Nutrients that have leached to deeper layers and that are no longer available for the commercial crop can be "recycled" by the crops in rotation. This way the rotation crops function as biological pumps. Furthermore, a diversity of crops in rotation leads to a diverse soil flora and fauna, as the roots excrete different organic substances that attract different types of bacteria and fungi, which in turn, play an important role in the transformation of these substances into plant available nutrients. Crop rotation also has an important phytosanitary function as it prevents the carryover of crop-specific pests and diseases from one crop to the next via crop residues. The effects of crop rotation include:

- higher diversity in plant production and thus in human and livestock nutrition;
- reduction and reduced risk of pest and weed infestations;
- greater distribution of channels or bio-pores created by diverse roots (various forms, sizes and depths);
- better distribution of water and nutrients through the soil profile;
- exploration for nutrients and water of diverse strata of the soil profile by roots of many different plant species resulting in a greater use of the available nutrients and water;
- increased nitrogen fixation through certain plant-soil biota symbionts and improved balance of N/P/K from both organic and mineral sources; and
- increased humus formation.

Annex 6 - Carbon sequestration and climate change mitigation

The adoption of conservation agriculture has an impact in terms of GHG balance. Emissions are reduced at field level due to lower (almost zero) topsoil disturbance by tillage and the maintenance of mulch. When properly managed, this process can sequester carbon from the atmosphere storing it in soils. Moreover, the reduced mechanized operations also imply a decrease in fossil fuel (mostly diesel fuel) consumption.

Sequestration rates under CA in Ukraine

Calculation of soil carbon (C) sequestration rates

Two approaches are possible (diachronic and synchronic) to calculate soil C sequestration rates of a new practice in comparison to a conventional one. The diachronic approach consists of measuring in years (t), on the same field plot, soil C stocks between time 0 (installation of the new system) and time x. The major disadvantage of the diachronic approach is that one must wait and measure over long periods of time before being able to evaluate the quantity of C sequestered. Therefore, estimates are generally based on a synchronic approach. The synchronic approach consists of comparing the C stock of a field plot, at a given time tn, (corresponding to the sequestering practice tested during × years) with that of a field (control or conventional practices) under traditional management which represents t0 state or the reference point. The major uncertainty of this approach remains the absolute comparability of the field plots which must be similar in terms of other soil properties (fertility, physical variable, hydrological properties, etc.).

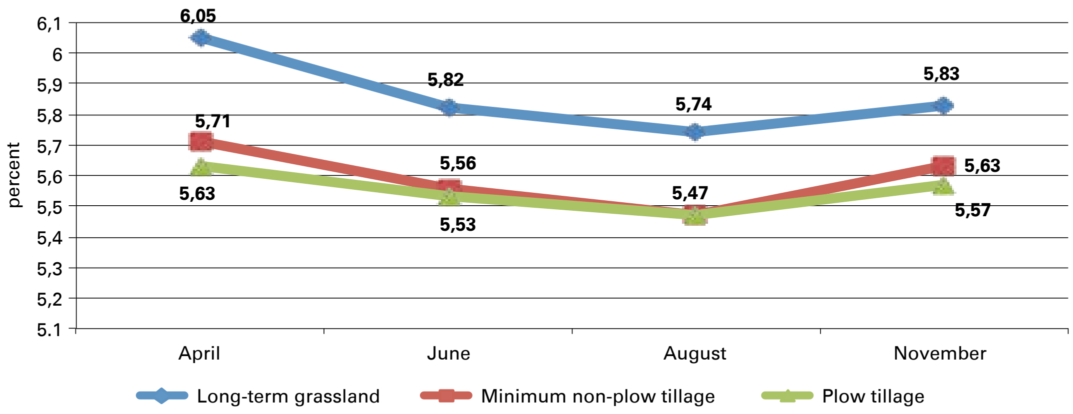
Sampling methods are vital to derive sound soil C sequestration rates in a scientific way. As Powlson *et al* (2011) highlighted "When quantifying a change in soil C stock, by comparing measurements taken at two times or by comparing two treatments or land uses, it is essential to take account of any change in soil bulk density[85] that has occurred. A relatively simple way of achieving this is to sample soils on an "equivalent mass basis" (sometimes termed "equivalent depth") rather than equal depths. This is important when there is likely to have been a change in soil bulk density (either over time or between treatments) and when, as is usually the case, the entire profile is not sampled. The principle is that an equal mass of organic matter-free mineral soil should be sampled between the treatments or times being compared." This has a direct implication when analyzing the performance of conservation agriculture in terms of C sequestration. For instance, considering the impact of the tillage systems observed in Ukraine and reported in Annex 1. Ukrainian soils, when the change in arable practice is from conventional tillage to zero tillage, it implies a small increase in bulk density of about 5 percent: if the conventionally tilled soil was sampled to a given depth (which should be slightly greater than cultivation depth), it is necessary to sample the soil after a period of zero tillage to slightly shallower depth in order to compare equal masses of mineral soil and correctly quantify any change in soil C stock.

Another determinant point concerns the temporal variability. For instance, Kapshtyk *et al.*[86] showed important C dynamics in Chernozems over a four-month period (see Figure 52). The period of the year of the soil sampling might be determinant in the calculation of the sequestration rates. If the objective is to compare different systems, sampling should be done at the same moment. Based on the curve below, the differences between conventional and no-till will be more evident in April or November.

85 Soil bulk density is an indirect measure of soil pore space which depends on soil organic matter content and texture.

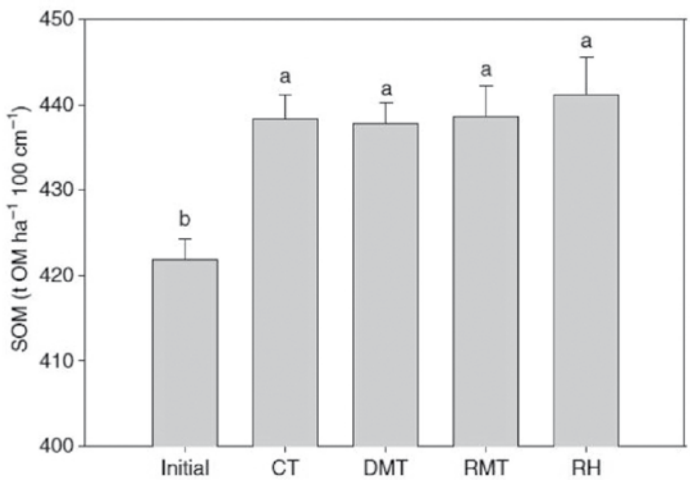
86 Kapshtyk M.V., Shikula M.K. L.R. Petrenko. 2000; "Conservation non-plough systems of crop production in Ukraine with increased reproduction of soil fertility". In: Soil Quality, Sustainable Agriculture and Environmental Security in Central and Eastern Europe NATO Science Series Volume 69, 2000, pp 267-276.

Figure 52: Seasonal cycles of humus in 0-10 cm layer of typical Chernozem, according to cropping system applied for more than five years



Source: Kapshtyk et al., 2000..

Figure 53: Influence of 10-year tillage on soil organic carbon (0-100 cm soil layer)



Different letters indicate significant differences (p-level of 5%) between tillage treatments: CT = Conventional tillage; DMT = deep minimum tillage; RMT = Reduced minimum tillage; RH = Rotary harrow (minimum soil disturbance in the top 6 cm).

Source: Kravchenko et al., 2012.

Table 31: Soil layer carbon content by technology

Soil layer (cm)	Tillage systems		
	Conventional (CT)	Minimal (MT)	Zero (NT)
	Carbon content (%)		
0-10	4.37	4.54	4.52
10-20	4.35	4.34	4.33
20-30	4.26	4.14	4.12
30-40	4.36	4.44	4.43
40-50	4.33	4.34	4.32

Source: Agrosoyuz JSC.

As a result, it is not straightforward to estimate sequestration rates based only on soil C content. The section below reviews the available information for Ukraine and the requirements to provide estimates of sequestration rates associated with the adoption of conservation agriculture in Ukraine.

Available data in Ukraine

Very few scientific publications (indicated in this annex) are available in English or with an extended abstract in English on the evaluation of the performance of reduced-tillage systems compared with conventional tillage systems. Few, if any, discuss comparisons with true CA/ no-till technology. Moreover, they deal nearly exclusively with physical properties (bulk density) or chemical properties linked with fertility parameters such as N and P content, Cation Exchange Capacity. Some papers presented results focused only on a particular fraction (or component) of the carbon pools: e.g. Kravchenko *et al.*[87] and Kapshtyk *et al.*[88]. These papers do not consent the calculation of the soil carbon sequestration rate.

Only one scientific paper reports C stocks in a typical Chernozem soil of Ukraine under different long-term tillage systems[89].

Even if the systems with the reduced tillage intensity have the highest C stock (441.2 t C/ha), the authors concluded that there is no significant difference after ten years, compared with CT (438.3 t C/ha). But it is important to highlight that the different treatments received NPK fertilizers (respectively 75, 68 and 68 kg/ha of N, P2O5 and K2O) with an important annual application of cattle manure at a rate of 12 tonnes per hectare. The authors added in their conclusion that synthetic and organic fertilizations had a greater impact on SOM concentration than the tillage practices. In other words, the tillage effect was masked in this experiment.

As there is a scarcity of published scientific papers in English, unpublished data can also be an important source of information. Agrosoyuz JSC reported the following information in terms of C contents.

Unfortunately, soil bulk measurements are not reported. This does not permit a direct calculation of C stocks, and then sequestration rates. It is known that soil management influences the bulk density (see Annex). In order to derive an estimate, the soil bulk densities reported by the same authors were corrected. As a result on an equivalent soil mass, soil carbon stocks were respectively 255.7, 257.3 and 256.4 tonnes C/ ha. Thus the benefit of no-till compared with conventional tillage seems modest and inferior to 1 tonne C/ha over the test period.

Other authors proposed to test the impact of different management practices in terms of fertilization and irrigation. Saljnikov *et al.*[90] presented detailed information on the soil carbon dynamics for 3 case studies in Ukraine (Kharkov, Uman and Kherson). In brief, the authors reported that:

- when comparing mineral and organic fertilizers (Uman): "The content of soil organic carbon was not increased after thirty six years application of mineral fertilizer in most of the treatments, compared with the control, while application of high rates of manure (O) alone maintained the higher accumulation of soil organic carbon"; and

87 Kravchenko Y.S., Zhang X., Liu X, Song C., Cruse R.M. 2011. Mollisols properties and changes in Ukraine and China. Chin. Geogra. Science, 21, 3, 257-266. DOI: 10.1007/ s11769-011-0467-z.

88 Kapshtyk M.V., Shikula M.K. L.R. Petrenko, 2000 "Conservation non-plough systems of crop production in Ukraine with increased reproduction of soil fertility". In: Soil Quality, Sustainable Agriculture and Environmental Security in Central and Eastern Europe NATO Science Series Volume 69, 2000, pp 267-276. http://link.springer.com/ book/10.1007/978-94-011-4181-9/page/1. Kapshtyk M.V., Shikula M.K., Balajev A., Kravchenko Y., Bilyanovska T. 2002; "The ways for an extended reproduction of soil fertility in Chernozems of Ukraine". In: Book of abstract, 2002 Bangkok Thailand 17th World Congress of Soil Science. (www.iuss.org).

89 Kravchenko, Y., Rogovska, N., Petrenko, L., Zhang, X., Song, C. and Chen, Y. 2012. "Quality and dynamics of soil organic matter in a typical Chernozem of Ukraine under different long-term tillage systems". In: Can. J. Soil Sci. 92: 429-438.

90 Saljnikov E., Cakmak D. and Rahimgalieva S. 2013. Soil Organic Matter Stability as Affected by Land Management in Steppe Ecosystems. "Soil Processes and Current Trends in Quality Assessment", book edited by Maria C. Hernandez Soriano, ISBN 978-953-51-1029-3, Published: February 27, 2013 under CC BY 3.0 license. 433 pages, Publisher: InTech, Published: February 27, 2013 under CC BY 3.0 license DOI: 10.5772/45835 (http://www.intechopen.com/ download/pdf/43223).

- when studying the impact of fertilization and irrigation practices (Kherson): there were no statistical differences for the top 0-20 cm. However, treatment with fertilization plus irrigation gave the best results.

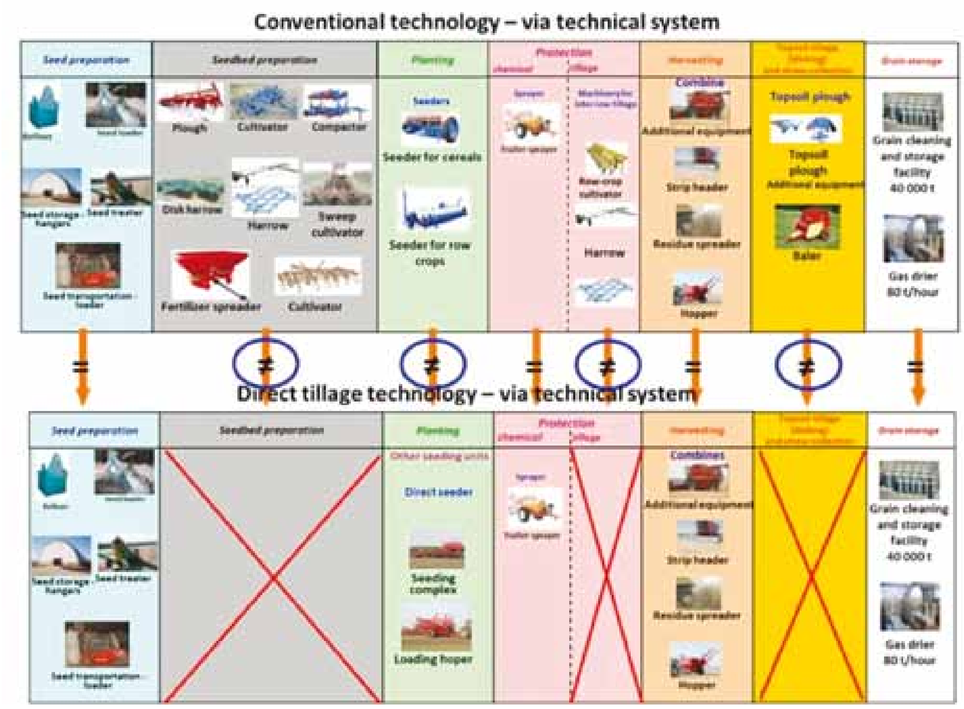
In conclusion, because the soil carbon content of Chernozem is high, up to several hundreds of tonnes of carbon per hectare in the top meter, it is really difficult to detect, in few years, variations of hundreds of kg of carbon. The calculation of soil C sequestration rates in Ukraine requires detailed and high quality determination of soil organic carbon plus soil bulk density.

In 2007, the IPCC published global estimates of soil carbon sequestration rates (net change considering all direct GHG, expressed as CO_2-eq) of broad sustainable land management categories, namely agronomy, nutrient management, tillage/residue management, water management, and agroforestry. Briefly, the "agronomy" category corresponds to practices that may increase yields and thus generate higher residues. Examples of such practices, reported by Smith *et al.*[91], include using improved crop varieties, extending crop rotations, and rotations with legume crops. Nutrient management corresponds to the application of fertilizer, manure, and biosolids, either to improve efficiency (adjusting application rate, improving timing, location, etc.) or reduce the potential losses (slow release fertilizer form or nitrification inhibitors). Tillage/residue management regards adoption of practices with less tillage intensity ranging from minimum tillage to no-tillage and with or without residue retention in the field. Water management brings together enhanced irrigation measures that can lead to an increase in the productivity (and hence of the residues). Agroforestry encompasses a wide range of practices where woody perennials are integrated within agricultural crops. Due to the scarcity of data, only simplified categories were used in compiling mean estimates of C sequestration potential on a global scale, according to major climate zone. In this simplified classification, the Ukraine climate corresponds to "Cool Dry" (southern part of the country) and "Cool Moist" zones (most of the northern part of the country). The corresponding carbon sequestration rates proposed for the no-tillage and residues management category is 0.15 tonnes CO_2-eq /ha /yr-1 for the Cool Dry zone and 0.51 tonnes CO_2-eq /ha /yr-1 for the Cool-Moist zone. These values correspond to sequestration rates of 0.04 tonnes C/ha /yr-1 and 0.14 tonnes C/ha /yr-1.

It is clear that on an annual per hectare basis, the level is small and certainly hard to detect, even in well conducted short- to medium-term experiments. This is made harder considering the annual variability (Figure 52). However, when applied to large areas, the numbers would be significant (see EX-ACT appraisal below, Table 32). Moreover, the scenario of adoption of conservation agriculture should be compared with the business as usual scenario. The construction of a baseline scenario is often required in analyses and prospective studies that aim at comparing different possible future situations. Thus, the dynamics of the soil organic content under a CA hypothesis must be compared with a baseline reference. Smith *et al.* reported that decrease of soil organic carbon will continue if no changes in management practices occur. Smith *et al.* reported an average loss observed for arable soils of 21 percent (with a range of 17-32 percent) based on statistical data for different Ukrainian regions, between 1881 and 2000. For a more recent period (1961 to 2000), there is still a loss of 11 percent on average. In absolute terms, the current decrease in Ukrainian croplands is estimated in the range of 0.35-0.55 tonnes C per hectare. This is a result of the decrease in organic fertilization (see Table 13) and suboptimal land management practices.

91 Smith J., Smith P., Wattenbach M., Gottschalk P., Romanenkov V.A., Shevtsova L.K., Sirotenko O.D., Rukhovich D.O., Koroleva P.V., Romanenko I.A., Lisovo N.V. 2007. Projected changes in the organic carbon stocks of cropland mineral soils for Europe, the Russian Federation and the Ukraine, 1990-2070. Global Change Biology, 13, 342-356.

Figure 54: Machinery and field operations
No-till systems compared with traditional ploughing



Source: Martial Bernoux..

Table 32: EXACT Appraisal

Description	Function	Method
Set of linked Microsoft Excel sheets for the insertion of data on soil, climate and land use of the considered project area.	Measure of the benefits of an investment project/programme through ex-ante estimates on GHG emissions & CO_2	Computing of the C-balance by comparing a situation without and with project.

Fossil fuel consumption

The adoption of CA would reduce farming operations (Figure 54) and thus fuel consumption. According to values collected during field visits, fuel consumptions range from 90-100 litres per ha for conventionally ploughed systems, to 60-80 litres per ha for minimum tillage systems and 25-40 litres per ha for no-till systems.

EX-ACT is a tool developed by FAO aimed at providing ex-ante estimates of the impact of agriculture and forestry development projects on GHG emissions and carbon sequestration. It indicates a project’s effects on the C-balance, an indicator of the mitigation potential of the project. EX-ACT was primarily developed to support appraisal in the context of ex-ante project formulation and it is capable of covering the range of projects relevant for the land use, land use change and the forestry sector. It can compute the C-balance by comparing scenarios: “without project” (i.e. the “Business As Usual” or “Baseline”) and “with project”. The main output of the tool consists of the C-balance resulting from the difference between these alternative scenarios.

EX-ACT has been developed using mostly the Guidelines for National Greenhouse Gas Inventories[92] complemented with other methodologies and a review of default coefficients for mitigation option as a base. Most

92 2006 IPCC (Intergovernmental Panel for Climate Change) Guidelines for National Greenhouse Gas Inventories.

calculations in EX-ACT use a Tier 1 approach[93] as default values are proposed for each of the five pools defined by the IPCC guidelines and the United Nations Framework Convention on Climate Change (UNFCCC): above-ground biomass, below-ground biomass, soil, deadwood and litter. It must be highlighted that EX-ACT also allows users to incorporate specific coefficients from project area, when available, therefore also working at Tier 2 level. EX-ACT measures carbon stocks and stock changes per unit of land, as well as Methane (CH4) and Nitrous Oxide (N2O) emissions expressing its results in tonnes of Carbon Dioxide equivalent per hectare (tCO_2e.ha-1) and in tonnes of Carbon Dioxide equivalent per year (tCO_2e.year-1).

EX-ACT consists of a set of Microsoft Excel sheets in which project designers insert information on dominant soil types and climatic conditions of a project area, together with basic data on land use, land use change and land management practices foreseen under the project's activities as compared with a business as usual scenario (Bernoux *et al*. 2010).

Basic assumptions for the ex-ante appraisal in Ukraine, which was performed to illustrate countrywide balance of GHG emissions after the introduction of CA, were the following:

- location is Eastern Europe;
- dominate climate is Cool Temperate Moist; and
- dominant soil type is HAC Soils (which correspond to High activity clay soil, e.g. fertile soils, of the IPCC classification).

Figure 55 shows the scenario of adoption and the baseline used in the assessment. The scenario of adoption corresponds roughly to a logistic function (also named "S-curve") starting from 2000, whereas the baseline (the without project option in EX-ACT) was set to a linear tendency. These dynamics were used in EX-ACT to calculate the benefit of adoption of no-tillage for the past period (2010 till 2013) and estimates for the future.

In terms of soil carbon sequestration, the linear trend corresponds to a total sink of 34.1 million tonnes of CO_2 sequestered (for the period 2000-2039). This includes 3.3 million tonnes already sequestered in the period 2000-2013. Thus without incentive for further no-till adoption, the benefit forecast is 30.8 tonnes of additional CO_2.

The Scenario of adoption corresponds to a total sequestration of 211.3 tonnes CO_2, from which 208 for the period 2013-2039. When comparing to the baseline, it means an additional benefice of 176.4 tonnes CO_2 in relation to the baseline. These results depend heavily on the assumption made for the climatic moisture regime. Table 33 shows the results obtained by EX-ACT when using the dry moisture regime. As the Steppe region is characterized both by moist and dry moisture regimes, it can be estimated that the overall benefice of the adoption of no-till systems will fall in the range 52.1-176.4 tonnes CO_2 with a best estimate close to 115 tonnes CO_2 eq.

The adoption of no-till will also result in reduced fuel consumption and consequent permanent emission reduction. Considering that a conventional system uses 95 litres per hectare in average and a no-till system uses 32.5 litres, the overall emission reduction can reach 45.7 tonnes of CO_2 equivalent compared with the baseline scenario.

93 IPCC Guidelines provide three methodological tiers varying in complexity and uncertainty level: Tier 1, simple first order approach which uses data from global datasets, simplified assumptions, IPCC default parameters (large uncertainty); Tier 2, a more accurate approach, using more disaggregated activity data, country specific parameter values (smaller uncertainty); Tier 3, which makes reference to higher order methods, detailed modelling and/or inventory measurement systems driven by data at higher resolution and direct measurements (much lower uncertainty).

Figure 55: CA adoption

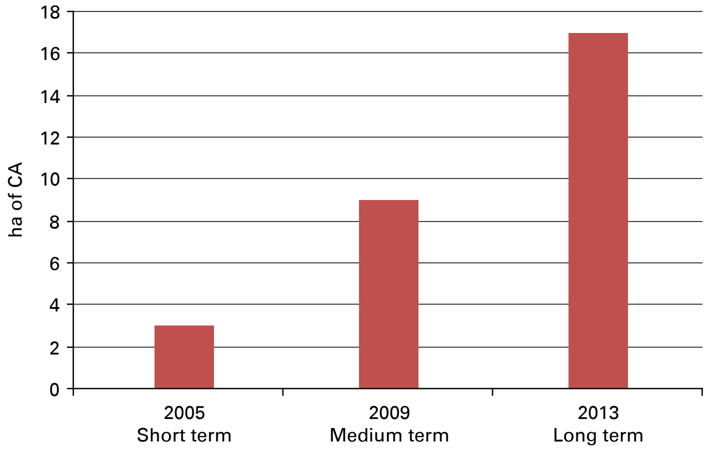


Table 33: Sensitivity of results to moisture regime

"Dry" and "Moist" moisture regimes

Scenario and period	Corresponding gross benefit (tonnes CO_2-eq)	
	Dry regime	Moist regime
Baseline - linear trend (2000-2013)	1.0	3.3
Baseline - linear trend (2013-2039)	9.0	30.8
Baseline - linear trend (2000-2039)	10.0	34.9
Scenario of adoption (2000-2013)	1.0	3.3
Scenario of adoption (2013-2039)	61.1	208.0
Scenario of adoption (2000-2039)	62.1	211.3

Annex 7 - Financial and economic analysis

Table 34: Ukraine: potential annual benefits from adopting CA

Level	Type	Per 1 ha	Benefits for 3 million ha (short-term)	Benefits for 9 million ha (medium-term)	Benefits for 17 million ha (long-term)
Annual farm benefits	Incremental net income	USD 136	USD 0.41 billion	USD 1.23 billion	USD 2.31 billion
Annual national benefits	Off-farm additional output value and additional soil fertility value	USD 123	USD 0.37 billion	USD 1.11 billion	USD 2.10 billion
Total national benefits		**USD 259**	**USD 0.8 billion**	**USD 2.3 billion**	**USD 4.4 billion**
% share of agricultural GDP			**6**	**18**	**34**
Annual global benefits	Improved food security (additional people fed during drought years, non-monetary benefit)	2.4 people	5.4 million people	16.1 million people	30.4 million people
	Reduced emission	0.5 tonnes CO_2 per year	1.5 million (equivalent to the emissions of 0.3 million cars)	4.4 million (equivalent to the emissions of 0.9 million cars)	8.3 million (equivalent to the emission of 1.7 million cars)
Total investment requirements	Investments in farm equipment and herbicides, plus research and extension	USD 200	USD 0.6 billion	USD 1.8 billion	USD 3.4 billion

Source: Team estimates.

The potential cumulative benefits deriving from a large-scale adoption of CA in Ukraine can be divided into the following three main types: farm/enterprise, national, and global level. The summary of the main economic and financial gains from CA introduction at each level is provided in Table 1 (repeated as Table 34).

Farm/enterprise level

As a result of the adoption of CA/no-till technology, agriculture enterprises are expected to obtain more stable yields, decrease the use of inputs and reduce land degradation. These factors can lead to a significant improvement of farm economic and financial efficiency. In this respect, we built a model to illustrate the efficiency of investment in conservation agriculture using a 4 000 hectare farm[94] as an example.

94 A 4 000 hectare farm was considered as a start-up farm size at the initial stages of no-till introduction. The underlying reason for this assumption was that 4 000 hectares farm can be serviced by two 6-meter wide seed drills (one disk and one anchor). These seed drills are among the smallest available in the Ukrainian agriculture machinery market.

The model was constructed to simulate investments profitability for three different crop production/land preparation technologies: conventional, minimum tillage, and CA/no-till. Assuming a 10 year project life and based on the cost-benefit analysis for each technology the model calculates – for each technology – specific and incremental[95] net incomes. The model simulates actual and incremental cash flows and calculates the main investment efficiency indicators such as investment and credit needs, and NPV.

The following crop rotation was considered: winter wheat, corn, sunflower and soybeans. The investment was calculated for each technology assuming a start-up business with all other conditions being the same.

95 No-till technology adoption as compared with conventional tillage and No-till technology adoption as compared with minimal tillage.

Table 35: Investments and depreciation

USD thousands	Conventional tillage	Minimum tillage	No-till
Investment in machinery	620	880	880
Tractors	180	360	360
Depreciation in %	15	13	10
Seeders	90	170	170
Depreciation in %	15	15	15
Sprayers	50	50	50
Depreciation in %	10	10	10
Harvesters	300	300	300
Depreciation in %	10	10	10
Other investments	500	880	1 360
Depreciation in %	5	5	5
TOTAL INVESTMENTS	1 120	1 760	2 240
Investment per hectare	280	440	560
depreciation per ha per year	25	38	41

Table 36: Crop budgets

USD per ha	Winter wheat			Corn			Sunflower			Soya		
	Conv.	Min.	No.	Conv.	Min.	No.	Conv.	Min.	No.	Conv.	Min.	No.
Seeds	180	180	180	141	141	141	78	78	78	92.4	92.4	92.4
kg	250	250	250	25	25	25	10	10	10	110	110	110
price (USD/kg)	0.72	0.72	0.72	5.64	5.64	5.64	7.8	7.8	7.8	0.84	0.84	0.84
Fertilizers	109	109	109	245	245	245	122	122	122	135	135	135
N (kg)	100	100	100	200	200	200	90	90	90	200	200	200
N price (USD/kg)	0.40	0.40	0.40	0.396	0.396	0.396	0.396	0.396	0.396	0.396	0.396	0.396
P (kg)	100	100	100	190	190	190	100	100	100	50	50	50
P price (USD/kg)	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.69
K (kg)	0	0	0	80	80	80	40	40	40	50	50	50
K price (USD/kg)	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43
Pesticides	11	11	11	7	7	7	4	4	4	5	5	5
Fungicides and other chem.	41	41	41	0	0	0	0	0	0	0	0	0
Herbicides	4	4	24	25	25	76	12	12	51	10	10	51
Fuel	110	66	33	110	66	33	110	66	33	110	66	33
L	100	60	30	100	60	30	100	60	30	100	60	30
price (USD/L)	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1
Total materials	455	411	398	528	484	502	326	282	288	353	309	317
Land lease	60	60	60	60	60	60	60	60	60	60	60	60
Machinery Maintenance	22	16	10	33	22	10	18	14	10	18	14	10
Labour	50	38	26	50	38	26	50	38	26	50	38	26
Product handling (per Tonne)	9	9	9	9	9	9	9	9	9	9	9	9
Total production costs	633	569	537	729	659	653	472	412	402	497	437	429

Table 37: Crop yields, prices and revenue

	Wheat	Corn	Sunflower	Soya
Yields (tonnes/ha)	4.7	6	2	1.8
Price (EXW, USD/tonne)	200	185	460	460
Sales	**940**	**1 110**	**920**	**828**

Minimum tillage and no-till are characterized by higher investment needs in machinery (more powerful tractors and modern direct seeding equipment) and additional investment cost for new technology adoption (considered under other costs in Table 35. This additional investment cost for new technology adoption was estimated at USD 240 per hectare for CA/no-till and USD 120 per hectare for minimum tillage; including the costs of maintaining productivity during the transition period (additional application of mineral fertilizers).

Based on anticipated machinery use (wear and tear) we assumed different depreciation rates and calculated depreciation cost per hectare. The model also assumed that different technologies may require various levels of replacement after full depreciation.

Financial needs for each technology were calculated by taking into account both initial investment capital (resources spent in purchasing and substitution of machinery and other assets) and operational capital (resources spent to cover first year operational costs and possible negative cash flows). Sixty percent of all the financial needs are expected to be covered by the farms own capital. The remainder is considered to be covered through loans from commercial banks at a 15 percent annual interest rate.

The estimated crop budgets for each technology and each crop are shown in Table 36.

Many of the costs in the crop budget of each technology are the same, while the main difference is determined by herbicides, fuel costs, machinery and labour costs.

Average reference yields were assumed to remain the same for each technology (see Table 37). These reference yields are expected to fluctuate over time with different intensity depending on the technology. In particular we assumed that yields over a three year cycle will be influenced by one normal, one favourable and one unfavourable year in order to reflect typical grain production variability. In the favourable year the yields under all three technologies should increase by 20 percent, but in the unfavourable year yields are expected to decrease by 25 percent with the use of conventional and minimum tillage technologies and only by 19 percent with the adoption of CA/no-till.

Sales revenues for each crop and technology were calculated based on EXW[96] demand prices (average over the last three years).
In order to account for the negative effects of erosion after the 5th project year, we considered a gradual decrease of yields up to minus 25 percent in farms adopting conventional tillage and up to minus 21 percent in farms adopting minimum tillage.

Based on the Ukrainian fiscal legislation applicable to the agricultural sector, a Single Agricultural Tax (SAT) was charged. SAT is calculated as 0.5 percent of the official value of agricultural lands used by the company.

Based on the above assumption, for each specific technology the following financial aggregates were calculated over a 10 year period: EBITDA (earnings before interest taxes depreciation and amortization, EBITDA = Gross Sales – Production Costs), net operative profit (Net Operative Profit = EBITDA – Depreciation), EBT (earnings before taxes, EBT = Net Operative Profit – Interest on capital) and net income (Net Income = EBT – Taxes). Based on a specifically designed net cash flow (Net CF = Net Income – Investment +Depreciation + Interests on capital) at a 15 percent discount rate (r) the NPV (NPV= – (Investment) + $\sum_{i=1}^{n} \frac{CF_i}{(1+r)^i}$) of the investments was calculated. Based

96 Ex Works.

Table 38: Main investment efficiency indicators for specific technology

USD thousands	Conventional tillage	Minimum tillage	No-till
Total investment	1 201	1 883	2 291
Total credit	1 380	1 535	1 704
inc. operational capital	*900*	*782*	*788*
Total loan servicing	277	336	405
NPV	4 723	5 523	6 685
Net income	8 766	11 286	15 473
Net income per ha (USD)	219	282	387

Table 39: Main investment efficiency indicators (incremental)

USD thousands	No-till Vs. conventional	No-till Vs. minimum
Additional investment	1 120	480
NPV	1 962	1 162
IRR	41%	41%
Net income	6 706	4 186
Net income per ha per year (USD)	167	104

on incremental net cash flow the model also calculates the incremental NPV and IRR[97].

The model has shown that additional investments required for the adoption of the technology (new machinery, investment in maintaining soil fertility and weed control during the initial stages of technology adoption, etc) are well recouped by the additional income generated.

Under the above-mentioned assumptions, our investment simulation model generated the following main efficiency indicators for each specific technology (conventional, minimum tillage and no-till).

In particular, CA/no-till farm with almost USD 2.3 million of investment can expect to obtain a NPV of over USD 6.6 million. Conventional technology is less demanding in initial investments and is characterized by lower NPV of USD 4.7 million.

With conventional technology farmers can expect on average USD 219 of net income per hectare per year, switching to CA/no-till allows them to increase net incomes to USD 387 per hectare per year.

97 Internal rate of return.

CA/no-till generates a positive incremental[98] NPV of almost USD 2 million over a -year project, compared with conventional technology. The corresponding incremental increase in the internal rate of return (IRR) approximates 41 percent; and an incremental annual net income of USD 167 per hectare. If compared with minimum tillage, CA/no-till generates: (i) a positive incremental NPV of USD 1.2 million in ten years; (ii) an incremental IRR of 41 percent; and (iii) an incremental annual net income per hectare of USD 104.

Based on the scale factor assumed in this analysis (adoption of no-till on 3 million hectares in the short-term, 9 million hectares in the medium-term and 17 million hectares in the long-term), the incremental net income from the introduction of no-till can generate a cumulated countrywide financial benefit to farmers would be[99]:

- short-term: USD 0.41 billion;
- medium-term: USD 1.23 billion; and
- long-term: USD 2.31 billion.

98 Indicators were calculated based on incremental CF which was calculated as the difference between specific CF of each technology.

99 The cumulated country-wide financial benefit to farmers was calculated multiplying average incremental net income by the scale factor.

Sensitivity of investment in CA/no-till to main risks

In order to evaluate the vulnerability of investments in each specific technology to risks, we also performed an investment sensitivity analysis. The main risk for Ukraine is the market risk. EXW demand prices in the country are strongly influenced by international prices and sharp declines of international grain prices are quickly transmitted from international markets directly to producers.

The sensitivity analysis took into account EXW demand price fluctuations. The analysis shows that investment in the CA/no-till farming model is more resistant to market risks than the conventional one. A CA/no-till farm would probably remain profitable even if grain sale prices decreased by 34 percent from the baseline scenario considered in the model. This is not the case of investment in conventional technology. The conventional tillage technology generates a negative return (NPV) if prices decrease by more than 24 percent.

Country level benefits

Reduced variability of production as a result of CA at the enterprise level can result in positive economic benefits at country and global level through increasing agricultural production and export stabilization, which will ultimately lead to improved global food security.

Reduction in volatility of national production of cereals and oilseeds is particularly important as it affects the country's capacity to export grains, oilseeds and vegetable oils. This aspect is particularly relevant in the light of highly volatile yields. In 2003, because of the lowest production of cereals and high grain exports in the previous marketing year, Ukraine had to import wheat. Based on what was considered a potential threat to national food security, MAPFU imposed bans on grain exports in 2006, 2007 and 2010. These three episodes caused not only economic losses for grain traders and farmers[100] but impacted negatively on the country's image as a reliable trade partner.

We assumed a reduction of crop production variability with the introduction of CA/no-till in our investment model (no-till technology mitigates the negative effects on yields in drought years by 25-35 percent). Reduction of production volatility would allow the country to maintain higher export levels during climatically unfavourable years.
On the basis of the scale factor assumed in this analysis, the introduction of CA/no-till would produce the following additional supply of cereals (wheat and corn equivalent) in drought years (once every three to five years):

- short-term: 0.3 million tonnes of wheat and 0.6 million tonnes of corn;
- medium-term: 1 million tonnes of wheat and 1.7 million tonnes of corn; and
- long-term: 2 million tonnes of wheat and 3.3 million tonnes of corn.

This additional supply of cereals is also expected to generate off-farm benefits (mainly to traders and intermediaries). In drought years (once every three to five years) additional benefits were estimated to amount to[101]:

- short-term: USD 54 million;
- medium-term: USD 161 million; and
- long-term: USD 304 million.

Additional benefits at the national level are expected to derive from the reduction of erosion as an effect of CA/no-till introduction.

The benefit from reduced soil erosion was quantified on the basis of expert estimates on SOM and NPK nutrient losses because of erosion in Ukraine. Of 32.5 million hectares of arable land, SOM losses amount to 20-25 million tonnes per year (0.6-0.8 tonnes of SOM per hectare per year) and NPK nutrients losses amount to 0.96 million tonnes of

100 Due to a fall of internal EXW demand prices.

101 The amounts were calculated with the assumption that the area under CA/no-till is cultivated only under wheat and corn. The total corresponding values have been computed in average FOB export prices minus EXW demand prices.

nitrogen, 0.68 million tonnes of phosphorus and 9.7 million tonnes of potassium per year. The market value of eroded NPK nutrients[102] amounts to over USD 5 billion per year (USD 157 per hectare). Adopting CA/no-till would reduce erosion by up to 75 percent and thus save about USD 117 per hectare. At country level (considering the adoption factor assumed in this analysis), the introduction CA/no-till would allow savings of:

- short-term: up to USD 0.35 billion;
- medium-term: up to USD 1.06 billion; and
- long-term: up to USD 2 billion.

The adoption of CA/no-till is expected to reduce fuel consumption for grain and oilseed production by 50 litres per hectare on average (70 and 30 litres compared with conventional and minimum tillage). At country level it will allow an average annual saving of:

- short-term: 150 million litres;
- medium-term: 450 million litres; and
- long-term: 850 million litres.

Based on fuel import prices the average values would be:

- short-term: USD 110 million;
- medium-term: USD 331 million; and
- long-term: USD 625 million.

However, such benefits have not been calculated at the national level. They have been considered exclusively as farm/enterprise level benefits.

Global level benefits

CA/no-till introduction is expected to generate benefits also at a global level. Additional amounts of cereals produced during drought years can reduce export supply volatility and thus contribute to improving global food security. Considering average annual consumption of 130 kg of cereals/per capita/per year, the increased supply of cereals deriving from CA/no-till area would be able to feed a further:

- short-term: 5.4 million people;
- medium-term: 16.1 million people; and
- long-term: 30.4 million people.

Carbon sequestration provides global benefits with a potential to generate income at national level. Benefits in terms of carbon sequestration and decreased emissions have been calculated through EX-ACT[103].Thanks to its capacity to mitigate CO_2 emissions, the introduction of CA/no-till in Ukraine can reduce annual CO_2 emissions by:

- short-term: 0.5 million tonnes;
- medium-term: 4.6 million tonnes; and
- long-term: 5.6 million tonnes.

Carbon markets are diverse, unstable and unreliable. For these reasons we avoid showing among the actual projected benefits those that would accrue by providing a value to the sequestered amounts of carbon in our scenarios. Should the reader want a value, at a price of USD 0.5 per tonne (Nasdaq Certified Emission Reduction[104]), the benefits from CO_2 reduction would amount to:

- short-term: USD 0.3 million;
- medium-term: USD 2.3 million; and
- long-term: USD 2.8 million.

102 AgroInvest UA Index, http://www.uaindex.net.

103 EX-ACT is a tool developed by FAO and aimed at providing ex-ante estimates of the impact of agriculture and forestry development projects on GHG emissions and carbon sequestration, indicating its effects on the C-balance, an indicator of the mitigation potential of the project.

104 However, considering CO_2 EU Allowances carbon is assumed traded at the same stock market at a price of USD 4.44 /tonne.

Annex 8 - Institutional settings

According to Regulation Nr.500 of MAPFU, approved by the President of Ukraine on April 23 2011, the Ministry is responsible for the formation and implementation of the Agrarian Policy of Ukraine. The Department of Engineering and Technical Support and Agricultural Engineering of MAPFU is a subdivision of the Ministry. The main tasks of the department are implementation of state policy on engineering and technical support and development of the national agricultural machinery production, which includes:

- development of standardization systems and certification of agricultural technical equipment;
- development and implementation of the measures aimed at technical and technological modernization of agriculture;
- development of energy saving technologies; and
- ensuring and promoting scientific research.

In the last decade, amongst the various strategic objectives of the Ministry and its departments, much emphasis was placed on soil fertility preservation in Ukraine. In view of the battle against soil degradation and loss of fertility due to erosion, for the last eight to ten years MAPFU has been advocating for the advancement of resources savings technologies in Ukraine and in particular of no-till[105]. This target is part of a strategy that was issued by MAPFU in 2007, the "State target programme of the development of Ukrainian village for the period until 2015". This programme outlines the urgent needs of innovation and investments in strengthening the material and technical base of the agricultural sector, the introduction of environmentally friendly, resource and energy saving technologies, implementing conservation of unproductive, degraded and contaminated agricultural land.[106]

The State Agency of Land Resources of Ukraine is the central executive authority on land resources activity. It is directed and coordinated by the Cabinet of Ministers of Ukraine through the MAPFU; it is included in the system of bodies of the executive power and ensures the implementation of state policy in the field of land relations.[107] This agency is the central executive authority on land resources activity and is responsible for all land legislation application and administrative matters, including the obligations to ensure preparation and performance of organizational, economic, ecologic and other measures directed at a rational use and protection of lands. Through a statutory State Committee of Land Resources it ensures preparation and performance of organizational, economic, ecologic and other measures directed at a rational usage of lands, their protection from harmful anthropological impact, as well as at increasing soil fertility and productivity.

UHMC[108] is responsible for meteorological, agrometeorological and hydrological data and information. The centre represents Ukraine at the World Meteorological Organization. As such it also participates in the implementation of the UNFCCC. UHMC has a modern approach to agrometeorology: "Agricultural meteorology has passed the development of qualitative, descriptive level of observations and assessments of soil and crops to modern methods of observations, including satellite information, modelling processes and phenomena occurring in the "agricultural object - environment"[109]. Agrometeorological observations are carried out at meteorological

105 ìSee http://www.kmu.gov.ua/control/en/publish/article?art_id=20455267&cat_id=244315200.

106 See http://minagro.gov.ua/apk?nid=2976.

107 See http://www.dazru.gov.ua/terra/control/en/.

108 See www.meteo.gov.ua.

109 http://www.meteo.gov.ua/.

stations located at a distance of about 50 km from each other (there is a network of 140 agro-met stations), that allows highlighting the agrometeorological situation at national level and in specific areas, with sufficient accuracy to obtain current weather conditions data and their influence on major crops. Agrometeorological information is produced daily and at fixed decade intervals. Observations include: phenology; crop height; crop population density; weeds, pest and disease damage; productive humidity; crop wintering and overall crop conditions' assessment. Main crops being observed are: wheat, rye, barley, canola, oats, corn, buckwheat, millet, peas, soybeans, sunflower, spring rape, sugar beet, perennial herbs, fruit and grapes.

The National Academy of Agrarian Sciences of Ukraine (NAAS) is a state research organization responsible for ensuring the scientific development of agricultural in Ukraine. It conducts fundamental scientific research in the field of agriculture by developing on the basis of the scientific knowledge of new products aimed at sector efficiency development. The NAAS is composed of 301 institutions, research institutes, centres and enterprises. The Academy employs 25 500 people including 5 000 scientists, 331 doctors and 1 698 science candidates. With the aim of the practical application of scientific achievements the NAAS has a vast network of associated institutes and research centres all over the country. In 2012 NAAS adopted a strategy of development of the agricultural sector (until 2020). The strategy aimed at development of an effective, resource-saving, environmentally-friendly, socially oriented, knowledge-based economy that can satisfy domestic demand and ensure a leading position in world market for Ukrainian agricultural and food products. The main problems of agricultural development accordingly to this strategy are:

- insufficient dissemination of highly innovative technologies, and their adaptation to the needs and economic possibilities of agricultural production;
- low level of innovation in the agricultural sector;
- slow technical and technological modernization; and
- consequent low productivity.

Amongst the main goals of this strategy are:

- increasing competitiveness of agricultural production;
- increasing manufacturability and decreasing use of input material in agricultural production;
- increasing share of the soil cultivated by using minimal or no-tillage technologies.[110]

The national Institute for Soil Sciences and Agro-chemistry Research (O.N. Sokolovskiy) of NAAS was established in 1959 as a successor of the Department of Soil Sciences at the Kharkiv Agricultural Institute and the Ukrainian Scientific-Research Institute for soil sciences of the Ministry of Agriculture of the USSR. Basic activities of this NSC include:

- development of the new scientific directions in soil science, agrochemistry and soil protection;
- scientific provisions of rational exploitation of the land resources, protection and increase of soil fertility;
- scientific justification of the national and state programmes;
- scientific-methodological standardization and metrological provisions in soil sciences and agro-chemistry industries;
- elaboration of the modern agro-technologies in soils fertilization and increase of soil fertility;
- preparation of scientific personnel;
- creation of modern soil/geo-information systems with the aim of improving the diagnosis of soils conditions, and their estimation and classification; and

Development of methodology of observation of soil coverage on the basis of modern technologies.

110 See http://uaan.gov.ua/.

Main achievements of the NSC include:

- large-scale soil mapping (1957-1961);
- soil grouping, zoning and classification;
- identification of regularities in soil processes and regimes;
- studies on soil fertility; and
- studies on erosion of soils.

Recently the Institute elaborated:

- strategy of balanced exploitation, reproduction and management of soil resources;
- national report "On state of Ukrainian soils fertility";
- concept papers on chemical amelioration of acid and salty soils; and
- concept papers on agrochemical procurement of agriculture for the period until 2015.

The National Scientific Centre "Institute of Agriculture"[111] of NAAS has a history going back to 1900 with the creation of the agrochemical laboratory of Kyiv Society of Agriculture and Agricultural industry to conduct analysis on soil samples and seeds in order to help increase agricultural productivity. Since then the Institute has developed significant theoretical information on crop rotation, optimization of seeding processes, anti-erosion measures and practices and fertilization.

The National Scientific Centre "Institute of Mechanization and Electrification"[112] of NAAS was founded on April 3rd, 1930 by Council decision of the People's Commissars of the Soviet Union. The Institutes main activities are:

- development of energy-saving technology;
- development mechanization, automationan delectrification of agricultural production; and
- creation of modern competitive machines, mechanisms, equipment and other technical facilities.

111 See http://zemlerobstvo.com/.

112 See http://nnc-imesg.gov.ua.

The development of machinery and technologies testing activities in Ukraine is directly related to the creation of the "Ukrainian Research Institute of Forecasting and Testing of Equipment and Technologies for Agricultural Production named after Leonid Pogorilyy" (Ukr SRIFTT named after L.Pogorilyy).

The National University of Life and Environmental Sciences of Ukraine (NULES) is one of the leading educational, scientific and cultural establishments of Ukraine. Over 37 000 students and more than 600 PhD Doctoral students are studying at 21 faculties of the Kyiv Territorial Centre, at the Southern Affiliate "Crimean Agro-Technological University" and at 12 regional higher educational institutions. Regarding the agricultural research sector, NULES educational activities are aimed at the dissemination of scientific and technical knowledge and advanced experience among employees of the agricultural economic sector, in order to improve their educational and professional level.

- The Department of Soil Science and Soil Conservation named after Prof M.K.Shykula[113] was founded in 1922. Students, post-graduate, and master students are involved in scientific work. The department presents a scientific school of conservation farming - research and development of soil cultivation technology based on minimum tillage and organic agriculture. Scientific works on soil conservation technologies were developed by the scientists of the Department on the basis of long-term field researches for the main soil-climatic zones of Ukraine, demonstrating the advantages that these technologies provide on soil properties and fertility and consequently on crop production.

113 See http://nubip.edu.ua/node/1232.

Please address questions and comments to:

Investment Centre Division
Food and Agriculture Organization of the United Nations (FAO)
Viale delle Terme di Caracalla – 00153 Rome, Italy
investment-centre@fao.org
www.fao.org/investment/en

Report No. 9 – June 2014

I3905E/1/06.14