Conservation Practices on Ukrainian Mollisols : A Mini Review

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Abstract **-** Mollisols are the primary soils in Ukraine. In order to maintain continued increases in grain production, Ukraine needs to implement conservation tillage and other sustainable land management to reduce soil degradation. The paper discusses the problem of Mollisols degradation and summarizes the influences of conservation tillage, cropping systems, fertilization, crop residue management, strip-cropping and contour farming on soil physical, chemical, and biological soil properties in Ukraine Mollisols for the past 50 years. Policies and relevant legislation in Ukraine are also outlined with an aim of providing guidelines and strategies in further implementing appropriate practices for sustainable use of Mollisol resources in the region.

Keywords: **-** Mollisols, Degradation; Erosion; Soil organic carbon; Conservation Tillage; Fertilizers.

I. INTRODUCTION

Worldwide use of soil resources was intensified dramatically ever since the beginning of agricultural civilization and domestication of plants and animals [1]. Land has been cultivated for 2500-3000 years in North and South American continents, 2000-4000 years in Western European and Mediterranean countries, 5000 years in the Middle East [2], and 4000-6000 years in Ukraine [3]. The transformation of natural grassland into crop or pasture land with improper anthropogenic activities such as lack of cover, less input, and overgrazing in particular resulted in an accelerated soil degradation and is of great concern in every agricultural region of the world [4].

Ukraine, the granary of Europe, witnessed a significant rise in productivity and efficiency during the first decade of the new millennium due to the intensity of its land use. The crop production in Ukraine reached 63 million t in 2014, which was 36.6% greater that of 2013. Ukraine set another record for corn output in 2014, producing over 30 million metric tons (MMT), placing country among the top five corn exporters in the world with the US, Argentina, and Brazil [5] Ukrainian grain export of wheat, corn and barley was in the eighth, third and first place of the world grain market in 2011 [6].

However, the country has to deal with soil degradation problems in maintaining its grain production momentum. The impact of Ukrainian agricultural production system on the environment contributed to 35-40% of the total environmental degradation [7]. It is estimated that over 8-10 million ha of farmland or 24.6-30.8% of arable lands is degraded and 4.5 million ha of farmland are in the moderate and severely eroded stages. The agricultural lands subjected to water erosion are estimated at approximately 13.3 million ha (including 10.6 million ha of arable lands). Over 1.9 million ha of these soils have been identified as wet or poorly drained. Irrigated land area decreased by 15% over the past 15 years [8]. More than 500,000 gullies are spread out on 140,000 ha of Ukrainian terrain. The soils with a lost surface horizon of humus accumulation occupy 68,000 ha. Approximately 600,000 ha of soils have been covered by medium and coarse textured clastic sediments. Annually, 6 million ha of lands are affected by wind erosion, while area affected by wind erosion increased to 20 million ha during the dust storm periods [9].

To combat soil losses and preserve soil fertility, Ukraine initiated regulations of soil conservation at the turn of the 19th century [10], and legislative conservation policies and field trials were implemented in 1954. According to the government directives, 851 benchmark sites were set up in all soil-climatic zones of the Ukraine. The interest in adopting soil conservation technologies in the middle 1950s appeared simultaneously with the rising wind erosion processes and soil degradation in Steppe regions of the former Soviet Union. For instance, the reclamation of 20 million ha of virgin soils in North Kazakhstan resulted in 1.2 billion t of humus losses in the 1950s [11], and these same areas suffered a much from the silt storms at the end of 1960s similar to “Dust Bowl” of the U.S. [12]. It is estimated that annual loss in Ukraine of humus was 10-15 million t, nitrogen 0.3-0.9 million t, phosphorus 0.7-0.9 million t, and potassium 6-12 million t with a reduction in crop yield of 20-60% on eroded lands [13]. All these problems are driven by human activities and will become even worse. To be sustainable, the food-producing systems should not undermine the natural resources on which food products depends soil [14].

Mollisols are the primary soils in the Ukraine, and account for 62% of all agricultural lands and approximately 78% of these soils have been cultivated [15]. Agricultural management

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strongly influences soil properties and the assessment of agricultural management on Ukrainian Mollisols may identify the degree these soils are degraded and thus provide priorities for policy-makers and stakeholders in adopting more appropriate practices and guidelines. This paper summarizes the influences of conservation tillage, cropping systems, fertilization, crop residue management, strip-cropping and contour farming on physical, chemical, and biological soil properties in Ukraine for the past 50 years from the perspective of Ukrainian scientists. The policies and relevant legislation in Ukraine were also outlined.

II. METHODOLOGY

A. Mollisols Distribution, Topography, Climate and Vegetation in Ukraine

Ukrainian Mollisols are known in other soil classification systems as Chernozems (Ukraine, Russia, FAO), Kastanozems and Phaeozems (FAO, WRB), Mollisols (USA), Isohumosols or Black Soils (China). For the purpose of this overview, the terms ‘‘Black Soils’’, ‘‘Chernozems’’ and ‘‘Mollisols’’ are used as synonyms. Ukrainian Mollisols are located in a 737 km north–south zone occurring from lat. 51°18´N to 44°41´N and an 1144-km-long east–west zone located from long. 24°18´E to 40°12´E [16]. The Podzolized and leached Mollisols are distributed across the well-drained uplands of the Forest – Steppe and watersheds. Typical Mollisols are widespread on upland plateaus between river valleys and terraces. Ordinary Mollisols occur everywhere in the northern subzone of the Steppe, covering the watershed plateaus. Southern Mollisols are common across the Black Sea lowlands and mid-Crimean peninsula, as well as being found on the flat plateaus of the South Steppe. Ukrainian Mollisols are formed in a temperate short with a relatively brief freezing period. In general, the climate of the Mollisols area is humid in the northwest, semi-humid in the middle and the semi-arid in the southern region, respectively. The vegetation type of Mollisols area in Ukraine is oak-maple-lime-hornbeam forests with grasslands and meadows in the north, and meadow, fescue, and needle grasses with greater xerophytic and halophytic species towards the south.

B. Study site and experimental design

Our experiment site is located on a Typical Mollisols area in the Forest-Steppe zone of Ukraine near the town Velykosnyatynka, in the Kyiv region (lat. 50°5′N, long. 30°2′E), which was conducted by the Soil Science and Soil Conservation Department of the National University of Life and Environmental Sciences of Ukraine. The average annual temperature is 7.9°C and 12.7°C in the vegetative period. The local climate can be defined as temperate with annual precipitation about 588 mm (291 mm in the vegetation period). Tillage treatments included conventional tillage (CT) based on deep plowing (25-30 cm), and two soil conservation tillage based on the deep minimum tillage (DT) to a depth of 25-30 cm, reduced minimum tillage (RT) to a depth of 10-12 cm, and minimized soil disturbance using a rotary harrow (RH) to 6- to 7-cm depth. The fertilizers supplied at rates $N_{50}P_{45}K_{45}$ ha^{-1} coupled with annual application of cattle manure at a rate of 12 t ha^{-1}. Corn was grown in crop rotation made up of five fields.

C. Sampling and Measurement

Composite soil samples (five cores per composite samples) were taken by using a core sampler (diameter – 6.0 cm) in the 0-10 cm depths. Soil samples were air dried and ground to pass through a 1-mm sieve. Soil moisture was determined by drying subsamples at 105°C for 24 h. A portion of each sample was ground to pass through 150 μm sieve to determine the SOC content. Humus composition was analyzed according to the method of Kononova [17]. Humic substances were extracted with a mixture of 0.1 M $Na_4P_2O_7$+0.1 N NaOH (pH=12.5). Then, the extract was separated into humic acids (HA) and fulvic acids (FA) by the addition of H_2SO_4 until the solution reached pH 1.3-1.5. The total carbon and carbon of HA from 0.1 M $Na_4P_2O_7$+0.1 N NaOH soil extractions were determined by wet combustion [18]. For other analyses, the gel HA was washed free of salts by using a dialysis membrane with a pore size of 2.5 to 3 nm and then freeze-dried. Analysis of the HA molecular mass composition was performed by the method of analytical gradient centrifugation for 5 h at 30 000 rpm with ρNaCl density gradient – 1.05 to 1.20 g cm^{-3}, and solution volume of 5 mL [19]. Dextrin and polyethylene glycol with Mw of 13.5 15, 20, 40, 70, 110, 600, and 1500 kDa were used as markers. Soil pH was determined on a 1:2.5 (V/V) soil/water mixture and measured then on a pH meter. Bulk density was determined on an oven dry basis by the core method. The undisturbed soil cores were taken at soil depths of 0–10 cm in early July. Infiltration of water into the soil was determined by the double ring infiltrometer [20], with a 20 cm inner diameter and a 40 cm outer diameter cylinder. For the review purposes, some data in the tables and figures were adopted from other sources. The bench-mark data and measurements could be found by use of corresponded references.

III. RESULTS AND DISCUSSION

A. Conservation tillage

For many centuries, agriculture has involved at least five separate operations: (1) tillage, (2) planting, (3) cultivating, (4) harvesting, and (5) processing, transporting, and storage before final consumption [21]. Tillage has historically been an integral part of the production process [22]. The effect of tillage is a process of physically manipulating the soil to storage a seedbed suited for seed germination and plant growth and is achieved by loosening compacted soil, breaking it for fineness and good soilseed contact, by burying crop residues and controlling weeds, and by optimizing moisture and aeration [23].

Traditionally conventional tillage in Ukraine often involved two major operations. The basic and primary operations used involved a hoeing plough, disc-harrows and/or chisel type cultivators, and moldboard plow in burying and placing fertilizers, manure, crop residues, while the secondary operations used spring-tooth harrows, seedbed levelers, packers, seedbed cultivators, star-wheeled rollers and other types of machinery [22, 24]. However, primary and secondary tillage were different as soil conditions changed. Conventional tillage used cultivation as the major means of seedbed preparation and weed control. The plowing was used to aerate the soil, decrease bulk density and compaction, and increase percolation of water at the soil surface. These advantages were important for farmers in making decisions to implement conventional tillage.

The moldboard plow inverts the furrow at least 135o, mixes and incorporates the residues and fertilizers within the tilled zone, displaces and shatters the soil aggregates and plant residues. Soil inversion is highly effective in burying crop residues and killing annual and perennial weeds (Fig.1) as well as volunteer crops [25]. Other studies have found that tillage systems disturb the weed seeds in different ways [26].

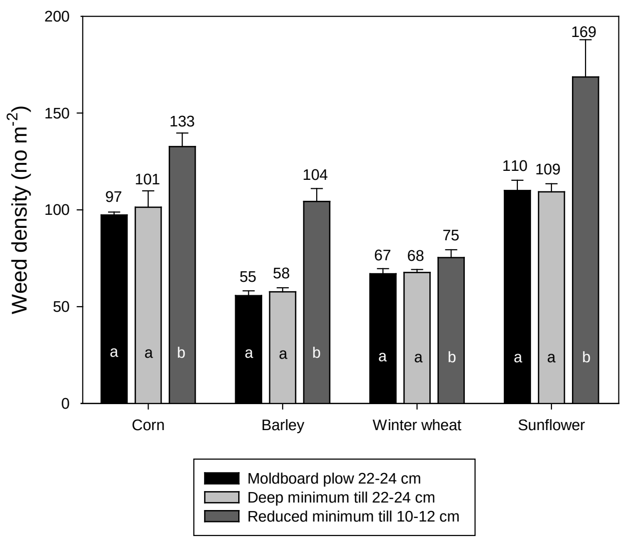

Fig.1. Tillage effect on density of weed population [25]. Columns (mean and standard errors, n=3) with different letters are significantly different (α=0.05 level) between weed density and tillage treatments.

The conventional tillage buries surface weed seeds in the lower 10-15 cm plow layer, whereas chisel plowing leaves the seeds closer to the surface, and with no-till, 90% of seeds remains in the 0-5 cm top layer (Fig.2). Continual tillage, however, can in some situations lead to soil degradation processes, such as organic matter decline, loss of soil structure and compaction, leaching of calcium and other soil nutrients [27]. Posing a high risk for crops, conventional tillage (moldboard plow) is seen as a major factor for increased erosion risks [28]. The numerous studies [22, 29-30] have shown preferences for conservation tillage for the effects on soil fertility improvement and soil erosion control. The modern concept of conservation tillage defines it as a non-inversion tillage based on: no-tillage, strip tillage, stubble mulching [31], zonal tillage, reduced or minimum tillage [32], direct drilling, and/or ridge-tillage with retention in all systems of at least 30% of ground cover by residues, and technologies that conserve time, fuel, money, labor, soil structure, nutrients, soil biomass, and soil water [33] and reduction in the number of passes over the field [34].

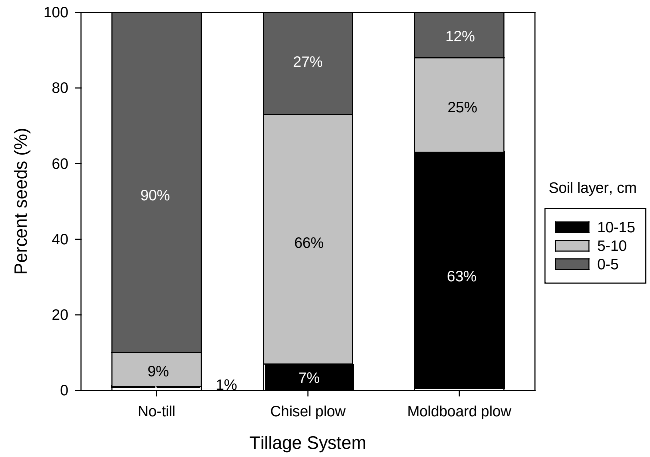

Fig.2. Vertical distribution of weed seeds in soil profile from different tillage [26]

The adoption of minimum tillage under winter crops in the South and South-East regions of Ukraine was successful, and about 50% of arable land area is now under no-till, minimum till, and disking, though conventional tillage practices are prevalent in the humid and semi-humid regions of Ukraine on Spodosols and Alfisols, respectively [35]. Our study, has been conducted on a Haplick Chernozem over a 7-yr period from 2006 to 2013 in the Forest-Steppe zone of Ukraine, showed increasing bulk density, compaction, infiltration rate, pH, soil organic carbon (SOC) concentration, carbon of humic acids (HA), carbon of fulvic acids (FA), molecular weight fractions humic acids (HA Mw) with minimization tillage (Table 1). However, reduced tillage systems had a higher proportion of SOCL, a lower ratio of C in humic acids/C in fulvic acids and more humic acids with molecular masses from 110 to 2000 kDa [36].

The guiding principles of this system were to reduce the number of row-crops (maize, sugar beets, sunflowers) and increase the number of cereals and leguminous grasses in rotations on the slopes. Clean fallows were substituted by green manure fallows. Degraded soils in field crop rotations were replaced by grasslands and forests. The greater parts of plant residues are now left in the fields. The system also introduces strip cropping across the slope, contour farming, shelter belts of forest trees and terraces on plowed land (Table 2). Tsilyurik [37] found that crop species impacted soil properties differently. Percentage of water stable aggregates in the size of 0.25-7 mm from the Steppe Mollisols cultivated

Table 1. Tillage effects on a Haplick Mollisols properties in upper 0-10 cm layer.

Tillage	Bulk density g cm^{-3}	Compaction kg cm^{-2}	Infiltration rate mm h^{-1}	pH	SOC g kg^{-1}	HA %	FA %	HA Mw kDa
RT	1.20 a	2.7 a	64.5 a	6.97 a	24.1 a	1 bc	0.39 ef	405053 a
DT	1.17 b	2.5 ab	41.8 b	6.82 b	22.9 b	0.98 cd	0.38 ef	367156 b
CT	1.17 b	2.2 b	41.2 b	6.57 c	22.2 b	0.96 d	0.34 f	275961 c

with alfalfa
(Medicago sativa L.) was 92.6%, and was decreased to 88.1% in pea, 87.7% in winter wheat, 85.8% in barley, 76.2% in corn, 77.4% in sugar beet, and 74.2% in sunflower. Crop rotation can affect soil properties and increase crop production. A long-term experiment by Gangu et al. [38] showed that yields of continuous sugar beet were 8.9-10.7 t ha^{-1} less than that of the rotation system. Still, 932,000 hectares of arable lands in Ukraine are in monoculture [39]. The frequency with which crops are grown affects crop yields. The data given in the Table 3 shows an advantage of five-year crop versus three-year rotation on cereals and sugar beet yields [40].

Table 2. Contour-ameliorative system of agriculture [41]

Land groups	Stage of erosion	Recommended land management
Plain lands and slopes up to 3º	Non-eroded and weakly eroded lands	Free crop rotation
Slopes 3º-7º	Moderately eroded lands	Grain-grass rotations without row crops (maize, sugar beets, sunflowers)
Slopes more than 7º	Strongly eroded lands	Long-term grasslands with legumes, grain grasses or forests

Table 3. Crop yields in tillage systems and crop rotations [40]. Different letters indicate significant differences (α=0.05 level) in crop yields between tillage treatments.

Tillage	Yield, t ha^{-1}			
	Cereals		Sugar beet	
	Number of crop years between the same crop in the cropping system			
	5	3	5	3
Plowing 22-25 cm	6.02 a	5.22 ab	58.2 a	52.4 a
Minimum tillage 22-25 cm	6.00 a	5.29 a	53.5 b	52.5 a
Minimum tillage 8-12 cm	5.95 a	5.01 b	51.4 c	47.2 b

B. Fertilization

Though Mollisols are fertile and productive soils, organic and mineral fertilizers are required to maintain their fertility. The increased yield from fertilizers was 50% in Forest Mollisols and 40% in Steppe Mollisols, and 20-15% and 40% respectively for these soils with irrigation [42]. The commonly used fertilizer rates (kg ha^{-1}) in typical Mollisols are: $N_{80}P_{70}K_{60}$ for winter wheat, $N_{80-120}P_{90-120}K_{120}$ + manure 30 t ha^{-1} for corn, $N_{60}P_{60}K_{40}$ for barley, $N_{90-120}P_{70-90}K_{40-60}$ + manure 20-40 t ha^{-1} for rice, $N_{60-80}P_{60-80}K_{40-60}$ for buckwheat, $N_{30-45}P_{45}K_{45}$ for soybean, $N_{160}P_{170}K_{150}$ + manure 30-50 t ha^{-1} for sugar beet, $N_{60}P_{60}K_{60}$ for sunflower, $N_{45-90}P_{60}K_{60-120}$ + manure 30 t ha^{-1} for potato, and $N_{90-120}P_{40-60}K_{80-120}$ + manure 20-30 t ha^{-1} for rape [43].

The way the soils are managed can improve or degrade their natural quality. Applying mineral fertilizers may increase soil acidity (all forms) and enhance the leaching of exchangeable bases. Soil organic matter loss is another of the major characteristics of soil degradation in the Ukraine. The data presented in Fig. 3 show that soil organic matter (SOM) content declined steadily in the first 60-year cultivation from the virgin Mollisols, and maintained at a relatively stable level in the following years [44].

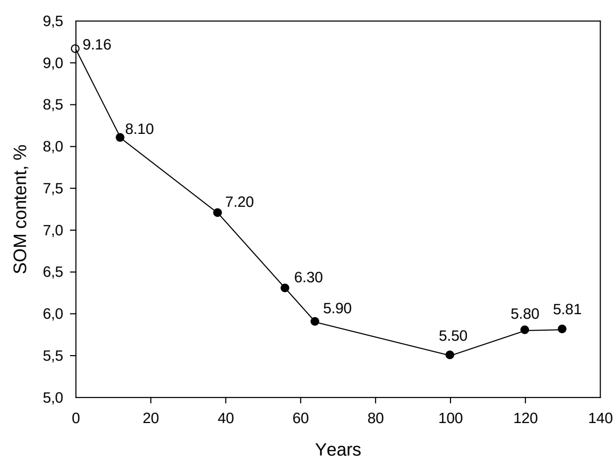

Fig.3. Effect of long-term cultivation of Typical Mollisols on SOM content, % [44].

Soil organic carbon (SOC) content can be recovered or even increased by applying cattle/pig/poultry manure, compost, peat, sapropel, green manure, plant residues, and cover crops. According the data of Hospodarenko et al. [45], 45-year manure application of increasing annual rates, noticeably increased percent base saturation, and available nutrient content, improving soil aggregation (Table 4). Increasing annual average solid manure rate from 9 to 13.5 t ha^{-1} allowed to increase SOM content from 32.4 to 34.3 g kg^{-1}, whereas

Table 4. Effect of manure rates (45 years) on Mollisol properties in upper 0-20 cm layer [45]. Different letters indicate significant differences (α=0.05 level) in soil properties between manure rates.

Average annual solid manure rates, t ha^{-1}	pH_{KCl}	Percent base saturation	Water stable aggregates, 10-0.25 mm, %	SOM, g kg^{-1}	Available nutrients, mmoles (+) kg^{-1}		
					$N\text{-}NH_4$	P	K
9	5.4 a	87.9 b	84.0 c	32.4 c	1.18 b	10.8 c	10.1 c
13.5	5.2 a	88.4 a	85.1 b	34.3 b	1.29 a	12.2 b	13.5 b
18	5.3 a	88.8 a	87.2 a	34.9 a	1.33 a	13.5 a	16.4 a

further increase of manure application annual rate to 18 t ha^{-1} resulted in a less pronounced SOM content increase (to 34.9 g kg^{-1}). Greatest value of total porosity (0.58 m^3 m^{-3}) and infiltration rate (23.85 mm hr^{-1}) was observed under the treatment of farm manure (FM) at the rate of 40 Mg ha^{-1}, followed by FM rate of 20 Mg ha^{-1} (0.41 m^3 m^{-3}, 15.00 mm hr^{-1}) and without FM (0.36 m^3 m^{-3}, 12.00 mm hr^{-1}).

Over the past several decades intensive cropping practices have led to the increasing demand for trace elements to the level higher than the soil can supply. A fundamental difference from traditionally used salt (ionic) form of fertilizers is a nanoform of mineral nutrients. A nanofraction, which is a result of melting and evaporation, followed by condensation of the vapor phase with an average sizes in the range of 10–150 nm and the corresponding structural phase composition of the solid phase, has signs of a biological functionality and can be used in plant growing. The use of pre-treatment of wheat seeds with colloidal solutions of metals, obtained by electrical discharge treatment, at an application rate of 2 liters per 1 ton of seeds and 2–3 times processing of plants during the growing season enhances winter wheat productivity by 15–20% on Typical Chernozem [46]. The colloidal forms of metals make a positive nutrient effect on the crops grown in calcareous and saline soils. The use of metal colloids normalizes the osmotic properties of cells, since the use of colloidal forms of metal for seed germination under saline conditions, stimulate the swelling and seed germination. Our data (Fig.4) demonstrate that under the salt stress conditions colloidal forms of manganese, zinc, cuprum, iron, unlike their salts increase the availability of this element for plants, facilitating its admission and participation in biochemical processes.

A. Green manure and cover crops

The use of green manure consists of incorporating non-decomposed vegetative matter into the soil with the objective of conserving or restoring the productivity of agricultural land [47]. Typical cover crops used are sudan grass (Sorghium vulgare), sugar sorghum (Sorghum saccharatum), Japanese millet (Echinochloa crus-galli var. frumentacea), panic (Panicum italicum), oat (Avena), barley, triticale (Triticale aestivumforme), Austrian winter pea (Pisum arvense), beans (Faba vulgaris Moench), bird's-foot (Ornithopus), soybeans, vetch (Vicia), lupine (Lupinus), oilseed radish (Raphanus sativus or R. sativus var. Oleiferus), winter and spring rape (Brassica napus) in the Forest-Steppe region of Ukriane. Maize, sorghum, Sudan grass, green foxtail (Setaria viridis), soybeans, pea everlasting (Lathyrus), winter and spring rape, panic, oilseed radish, summer rape (Brassica campestris), and runchweed (Sinapis alba) are available in the Ukrainian Steppe.

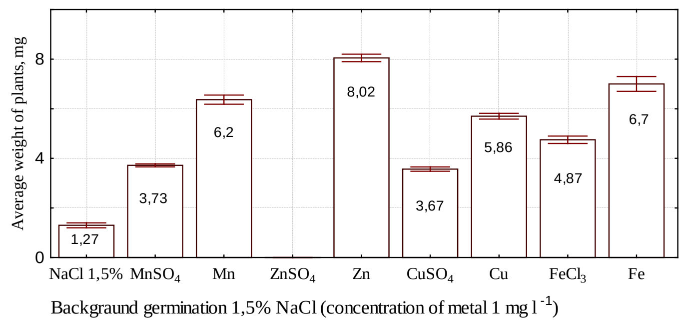

Fig.4. Effect of salt and colloidal metals on watercress sprouts biomass after 5-days expose in 1,5% NaCI solution.

Cover crops are usually grown together with winter or spring crops in sequence or planted after harvesting. They are grown as autumn/winter annuals and ploughed in to form a green manure prior to sowing the main crop. Total incorporation of 40 t ha^{-1} lupine biomass into soil brings in 180 kg N/ha^{-1}, 40 kg P/ha^{-1}, 68 kg K/ha^{-1}, which is equivalent to 15-30 t ha^{-1} of manure [48]. Cover crops not only influence soil properties but also increase crop production. Results obtained by Datsko & Stcherbatenko [49] demonstrated that the use of cover crops increased yield by 0.17-0.43 t ha^{-1} in winter wheat, 5-9 t ha^{-1} in potato, 5-14 t ha^{-1} in sugar beet, 7-13 t ha^{-1} in silage corn, 0.9-1.3 t ha^{-1} in grain corn, and 0.6-1.0 t ha^{-1} in buckwheat.

Inter crops in Ukraine are most commonly sown between the rows of the commercial crops in developing an intercropping system, which is particularly beneficial to soil quality improvement or when the soil has to be used as intensively as possible. The widespread intercropping systems are winter wheat + lupine, winter wheat + holy clover (Onobrychis), maize + blackgram (Vigna mungo), maize + pea, winter rye (Secale cereale) + bird's-foot, winter barley + alfalfa (Medicago sativa) in Ukraine [50]. A mixture of clover (Trifolium) with cereals is recommended to be adopted in humid areas, alfalfa with holy clover in semi-arid areas, alfalfa (Medicago falcate, Medicago caerulea) with awnless brome (Bromopsis inermis) or wheat grass (Agropyron) in dry regions [51]. Mixed grasses of the poaceae (Gramineae), with the fabaceae/leguminosae (Faboideae) and the crucifers/cabbage (Brassicaceae) family are usually grown in eroded lands to achieve highest yields of fodder crops [52].

B. *Mulching and Crop Residue*

Mulching is the practice of covering the soil surface with a layer of natural/plastic material. Mulches can either be organic (grass clippings, leaves, hay, straw, bark chips, sawdust, shells, woodchips, shredded newspaper, composts) or inorganic (stones, brick chips, rubber and plastic). Eroded Ukrainian Mollisols require the application of mulches at rates depending on soil texture: 1.3 t ha^{-1} for sandy loams, 1.9 t ha^{-1} for sands, and 1.1 t ha^{-1} for silt loams [53]. Tsvey et al. [54] reported that increasing application rates of cereal straw from no mulch, 2.5 t ha^{-1}, 5 t ha^{-1} and 5 t ha^{-1} + N_{30} resulted in additional sugar beet seed yields of 1.31 t ha^{-1}, 1.41 t ha^{-1}, 1.54 t ha^{-1}, and 1.67 t ha^{-1} respectively. The effect of incorporated mulch depends upon the material used. Univer et al. [55] found higher strawberry yields were obtained from mulches of white clover (Trifolium repens L.), timothy (Phleum pratense L.), Kentucky bluegrass (Poa pratensis L.) and red fescue (Festuca rubra L.). While implementing mulches, it is important to consider the carbon to nitrogen ratio of the organic residues as the organisms consume the soil N and immobilize it if the C:N ratio is above 25. In order to overcome nitrogen deficiency in Ukraine10-15 kg N/ha^{-1} and 8 kg P/ha^{-1} of chemical fertilizers are applied for each metric t of straw [56]. The effectiveness of mulching in reducing erosion was demonstrated in the field experiments in typical Mollisols [57]. Minimal tillage with 2.5 t ha^{-1} mulch in the eroded Mollisols saved greater amount of available water for the plants, reduced runoff up to 3.8 m^{-3} ha^{-1}, and increased spring barley grain yield by 1.6 t ha^{-1}.

Other benefits of mulching compared with traditional fertilizer system, are the decreases of CO_2 emission (1.45-1.56 fold), increases in cellulose decomposing capacity (1.94-2.24 fold), and the number of earthworms (1.8-2.2 fold) [58]. Zaharova [59] also indicates that mulching increased soil nitrate nitrogen by 14-16%, and sunflower yield by 16%. Exponential decrease in the rate of soil loss with the increasing in the percentage area covered by mulch has been reported [60-61] with the mulch factor (MF) expressed as:

MF = e-a.RC,

where RC is the percentage residue or mulch cover, a is a value ranging from 0.01 to 0.07, depending on the degree of soil disturbance by tillage. For undisturbed soil surfaces, the a value is equal to 0.05 [62]. Chornyy et al. [63] demonstrated the effects of mulching on combating soil deflation. Deflation factor in southern Mollisols increased from 0, to 0.01, 0.08, 0.17, 0.29 for sorghum to soybean, white mustard, green pea, and winter wheat under no-till and was 0.16 to 0.70, 0.86, 0.58, 0.74 under conventional tillage respectively.

C. *Strip Cropping*

Strip cropping is a method of growing row crops in alternating strips following the contour of the land, in order to minimize erosion [64]. Strip cropping is often applied in slopes exceeding 2° steepness or/and 150-200 m length field. Deep heavy-rooted plants in this arrangement should alternate with loosely-rooted plants. The strip widths on 3° slopes are usually about 60-70 m for corn/rape/sunflower, and 70-150 m for spring-winter cereals. The widths of buffer strips made up of grasses and legumes should be no less than 4-6 m on 3° slope and 8-10 m on 3-7° slopes [65].

Contour farming is not recommended for areas where the slope is less than 1° and the slope is not long [66]. For the field with 1-3° slopes, common practices carried out are: plowing along the lines of the contours, 1-3 m buffer strips comprised of buckwheat, phacelia (Phacelia), oats, annual legumes planted at intervals of 60-80 m; 6-8 m wide forest belts along the field margins and perpendicularly to the wind direction; contour ridges or channels established at 160 m intervals; mulching with cover no less than 65 per cent of the soil surface; establishment of permanent vegetation barriers; growing multiple crops for use in rotations, and application of an additional 10-15% chemical fertilizers. For the fields with 3-7° slopes, recommended practices are: alternative strips across the slope parallel to each other in breadth of 60-80 m under annual grasses mixed with cereals or 20-40 m under corn-legumes mixtures; crop rotations with 40% cereals and 60% legumes; forest belts mixed with bushes 8-10 m wide at an interval of 200 m; mulching cover no less than 75% of the soil surface; additional 15-20% fertilizers applied. For steeper slopes with very erodible Mollisols, the top priority practices are: growing perennial forage and pasture crops. The benefits of contour farming can be enhanced by combination with the other relevant conservation practices suitable to local soil, relief/geology and climate conditions [67].

Contour bunds, suitable for slopes 1-7°, are 1.5-2 m wide, 0.25-0.4 m high, spaced at 18-50 m intervals, which were built across the slope to form a water storage area on their upslope side and frequently used in a strip-cropping systems covered by vineyards, gardens, and shrubs. Ivanytska [68] found the earth bunds increased the effective volume of plum roots to 515 m^3, as compared to 347 m^3 on the slopes without the bunds. Soil total porosity increased to 55%, compared with 49% on the slopes without the bunds, and soil bulk density improved to 1.23 g cm^{-3}, as compared to 1.33 g cm^{-3} on the slopes without bunds.

Terracing across the slope intercepts surface runoff and minimizes soil erosion. Three classes of terraces are employed in Ukraine: diversion, retention and bench. The common ground terraces are normally used on slopes less than 7°, with the embankment up to 1 m high and 3-12 m wide [69]. Terracing and slope steepness affect the Mollisols morphological features. Svitlichniy and Chorniy [70] reported that the soil on the terraced slopes lost less nitrogen, phosphorus, potassium and calcium as compared to non-terraced slopes. Zuza [71] reported a significant improvement in snow-trapping and available water storage (by 12-26 mm) with terraces. The same phenomena were earlier reported by Gichka and Timchenko [72] in spring on terraced slopes.

D. *Policy and legislation in Ukraine*

Being a member of Council of Europe since November 1995, and an active participant in the “Environment for Europe” process, Ukraine inherits numerous European obligations and has its own legislation with corresponding measures in soil protection. More than 400 policy measures were developed by EU Member States [73] The soil-relevant policies, addressed to soil degradation, can be outlined in four categories: mandatory measures, voluntary incentive-based measures and awareness-increasing measures and private initiatives [74-75]. The European Commission Directive COM (2002) 179 final “Towards a Thematic Strategy for Soil Protection” [76] is one of the most relevant to soil conservation. This Directive describes the multiple functions of soils, identifies the main threats to soils (erosion, decline in soil organic matter and biodiversity, soil contamination, soil sealing, soil compaction, salinization, floods and landslides), and changes in soil characteristics relevant to policy development. The Sixth Environment Action Program of the European Community entitled "Environment 2010: Our Future, Our Choice" defines the priorities and objectives of European environment policy up to 2012 dealing with a coherent approach to soil protection with legislation, integrating environmental concerns, partnership with business, empowering citizens and changing their behavior, and taking account of the environment in the land-use planning and management [77]. There are a number of directives regulating soil quality, such as the “Nitrates Directive” 91/676/EEC and the “Water Framework Directive” 2000/60/EC, combined with the “Groundwater Directives” 80/68/EEC and new directive 2006/118/EC. Holistic approach in soil protection and sustainable land use was also targeted in “Soil Framework Directive” COM (2006) 232 [78] and “Global Environment Outlook” [79].

The National Ukrainian legislation takes into account interrelationships between soil friendly practices to decrease soil degradation and direct policy measures. The Land Code of Ukraine (effective from January 1, 2002) is the most advanced and closest to European legislative norms. It defines legislative codification and summarizes the rules, regulating land relations into a coherent system, built upon unified principles, taking into account the world experience and requirements regarding harmonization of Ukraine’s legislation with legislation of the European Union. Some norms of this act contain direct guidance for land protection, use, reclamation, recovering of contaminated and damaged soils, restoration of soil fertility, standards in land protection, and state oversight of land use and conservation [80]. The legislative authorities, responsible for budget initiation and regulation in land/soil conservation, are the Ministry of Agrarian Policy and Food, Ministry of Ecology and Natural Resources, The State Agency of Land Resources, State Forest Resources Agency, State Water Resources Agency, and the Statute of the National Environmental Investment Agency of the Ukraine [81]. All environmental principles of land protection are embodied in the Ukrainian Constitution.

All agricultural lands in Ukraine, according to the President Decree № 1118/95 and Directive №536 [82], must possess an agrochemical passport. The certificate includes common soil parameters (soil organic matter content and its distribution downwards soil profile, soil texture, storage capacity of available for plants water, acidity, salinity, soil nutrients and microelements content) as well as the concentrations of the soil contaminants determined by the regulations № 4433-87 “Sanitary code of MPC (maximum permissible concentration) of chemical substances in soils”. The sanitary condition of the Ukrainian soils is also determined by the State Standard №17.4.2.01-81 “Nature Protection. Soils. Nomenclature of sanitary condition indices” [83]. According to the law “On State Control over Use and Protections of Lands”, the control of land use and protection is carried out by the authorized body of The State Agency of Land Resources. The control of the observance of laws for soil protection is fulfilled by the authorized body of Ministry of Ecology and Natural Resources, and the monitoring of soil fertility is fulfilled by the authorized body of Ministry of Agrarian Policy and Food [84]. Some older legislative acts contain direct operating instructions for soil management: Directive №320 from 16.05.1967, “Immediate measures of the soil protection against of wind and water erosion”, Directive №407 from 02.06.1976, “On land reclamation, conservation and rational use after open-pit mining”, but now they are not widely used because of the adoption of new scientific approaches, technology, and standards of soil conservation. The principles of ecological policy in management of land resources are governed by the law “On Environmental Protection”. This law enacts norms for environmental state inspection, assessment, standardization and liability of infringement [85].

IV. Conclusions

According to our findings, the practices of no-till & minimum tillage with the application of 2.5 t ha^{-1} of shredded cereal straw, resulted in 1.31-1.67 t ha^{-1} added yield of sugar beet, surface runoff reduction up to 3.8 m^{-3} ha^{-1}, increases in SOM concentration, infiltration rate, pH, and the amount of available N, P and K. This effect is enhanced by the use of an eight-ten field crop rotation, enriched by small grain crops and leguminous forages. The commonly used fertilizers in conservation agriculture include full NPK rates plus manure of 12 t ha^{-1} in the humid zone, 10-12 t ha1 manure in semi-humid zone and 8-10 t ha^{-1} manure the in semi-arid zone of the Mollisol region. Green manure, cover crops and inter crops increased yield by 2-10% on Forest-Steppe and Steppe Mollisols. The combination of strip cropping, contour farming, contour bunds, and terracing are particularly recommended for sloping in order to minimize soil erosion, water losses and provide sustainable management practices on sloped farmland. The Ukrainian government is keen to address all recognized soil degradation processes through legislation. However, few policies are relevant to soil conservation or do not address soil degradation, and even if they do, are not oriented towards specific results of improved soil quality with appropriate farm management. Overall, all of these policies and measures have broad scopes of action but are not sufficient to ensure an adequate level of soil management. Obviously, further development of conservation agriculture in Ukraine should be based on updated government policies, strategies, and integrated programs to encourage voluntary adoption by the farmers and other land managers in both crop production and the preservation (conservation) of sustainable environment.

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