ARTICLE IN PRESS

Energy xxx (2014) 1–7

Contents lists available at ScienceDirect

Energy

journal homepage: www.elsevier.com/locate/energy

Impact of energy saving cultivations on soil parameters in northern Kazakhstan

Elmira Saljnikov [a,*], Aleksandar Saljnikov [b], Saule Rahimgalieva [c], Dragan Cakmak [a], Mirjana Kresovic [d], Vesna Mrvic [a], Temirbolat Dzhalankuzov [e]

[a] Soil Science Institute, Teodora Drajzera 7, 11000 Belgrade, Serbia
[b] Mechanical Engineering Faculty, Belgrade University, Serbia
[c] Faculty of Agronomy, West-Kazakhstan Agrarian-Technical University, Kazakhstan
[d] Faculty of Agronomy, Belgrade University, Serbia
[e] Institute for Soil Science and Agrochemistry, Almaty, Kazakhstan

A R T I C L E I N F O

Article history:
Received 5 November 2013
Received in revised form
13 February 2014
Accepted 10 March 2014
Available online xxx

Keywords:
Energy saving cultivation
Soil organic matter
Tillage depth
Enzymatic activity

A B S T R A C T

Recently the cost of soil processing for agricultural production has been rapidly increasing because of expensiveness of agricultural machinery, energy, and agricultural chemicals. Intensive soil cultivation is costly and adversely affects soil fertility due to accelerated mineralization of soil organic matter. By minimizing mechanical disturbance to the soil, costs can be reduced and the environment enhanced. About half of the global CO_2 emissions from the soil come from decomposition of the annual plant litter including agricultural crops. We studied methods of soil tillage that would help stabilize the yield of crops while maintaining soil fertility and saving energy and labour at the same time. Three types of crop cultivation experiments were studied: 1) cultivation intensity (simplified ST, common CT, and intensive IT); 2) tillage depth (shallow S, and deep D subsoil till), and 3) minimum MT, and zero till ZT. The results showed that under ST the soil biological parameters were more favourable than under CT and IT. Shallow subsoil till maintained higher levels of soil nutrients, and reduced CO_2 emission compared with the deep subsoil till. The minimum and zero tills positively influenced soil physical and biological properties through improvement in soil aggregate stability and soil enzymatic activity.

1. Introduction

Energy input and output differs widely among crops, production systems and management intensity. Yield of primary agricultural production is positively correlated with energy input. Differences in cropping practices, such as tillage, have considerable effects on energy efficiency of crop production systems. The most energy-consuming process in crop cultivation is soil processing that consumes an average 30–40% of the energy input in agriculture [1–3]. Total input of energy used per hectare increases with the increase of management intensity [4]. Therefore, selection of the appropriate tillage method includes assessments of the system's efficiency control [5].

Also, mechanical disturbance of soil is one of the most significant factors that determine deterioration of soil fertility. Losses of humus under agricultural use are determined by biological (domination of mineralization processes over humification) and mechanical (reduction of thickness of humus layer caused by erosion and destruction of soil aggregate stability) factors [6,7,33].

Continuous intensive mechanical disturbances can cause both soil environmental (depletion of soil fertility; compactness of soil etc.), and energy related problems (higher input of human and mineral resources, etc.) [8–17]. About half of the globally CO_2 output from soil comes from the decomposition of the annual plant fall [18] including agriculture. Therefore, minimization of soil tillage can also contribute in another key environmental issue as carbon sequestration.

Traditional technology of cultivation of crops with spring moldboard till and repeated seasonal harrowing is characterized by high energy and labour cost. Therefore, one of the ways to save energy and sustain soil environment is introduction of the

* Corresponding author. Tel.: +381 112667175, +381 637409123 (mobile).
E-mail addresses: elmirasal@mail.ru (E. Saljnikov), sasaljnikov@gmail.com (A. Saljnikov), saule-ra@mail.ru (S. Rahimgalieva), ktomi@eunet.rs (M. Kresovic), d.temirbolat@mail.ru (T. Dzhalankuzov).

http://dx.doi.org/10.1016/j.energy.2014.03.042
0360-5442/

technologies with reduced mechanical operations on soil, both in the number of operations and the depth of plough.

Dry-steppe areas of northern Kazakhstan are characterized by very low precipitation (mean annual rainfall is 350 mm) and by strong winds causing soil erosion. Therefore, the cropping technologies that could maintain soil moisture and prevent soil erosion were introduced in the area. The crop requirements for water have being solved via moisture accumulation through introduction of snow retention. The wind derived problems were solved by replacing the traditional moldboard till by subsoil till. The nutrient accumulation problems were solved through bare-fallowing.

Retention of snow through making snow ridges is very effective measure for moisture accumulation during the winter. In spring the water from snow ridge is better absorbed into soil and less evaporated. The subsoil till greatly protects soil from wind erosion because of the crop stubbles left after harvest on the field. Bare fallow is the field in a cropping sequence that is not planted but is actively cultivated during the whole vegetation season. Therefore, such intensive mechanical disturbance might result in decrease of soil fertility via intensified mineralization of soil organic matter.

Where soil is often intensively manipulated, the effect on soil organic matter (SOM) is especially pronounced [19]. On one hand, intensive soil cultivation ensures better oxidation conditions for soil microbes, thus intensifying mineralization processes in soil and ensuring plant nutrients and thus crop yield. On the other hand traditional cultivation consumes much more energy, resources and labour inputs, as well as an accelerated mineralization leading to the depletion of natural SOM. The labile fractions of SOM (mineralizable carbon and nitrogen; microbial biomass) proved to be reliable indicators to respond to subtle changes in cropping technologies [19]. Variable direct energy costs (1–6%) depend on cropping system and increase to 7–10% when indirect consumption (e.g. fertilizers and seeds sown) is included [3].

The goal of this study was to research the optimum soil cultivation intensity in terms of preservation of soil fertility and saving energy through studying the physical and biological properties of soil in dry-steppe of northern Kazakhstan.

2. Materials and methods

The long-term field experiments were carried out at the Kazakh Research Institute of Grain production in Shortandy, Astana, northern Kazakhstan (51°35′36″, 54N; and 71°10′15″, 40E) on *Typic Haplustolls* [20].

Three experimental cropping scenarios were studied: 1) *cultivation intensity* (simplified, ST; common, CT; and intensive, IT); 2) *tillage depth* (shallow till, S, and deep till, D); and 3) *minimum and zero till* technologies in the standard wheat production system.

The ST implies no additional agronomic inputs; the CT includes making 35 cm snow ridges in winter and phosphorus fertilization in spring; the IT implies making 40 cm snow ridges and phosphorus and nitrogen fertilization (Table 1).

In the tillage depths experiment soils were sampled from the two phases of fallow-wheat cropping cycle. Both the shallow (S) till and deep till (D) were sampled immediately after fallow year (S1 and D1) and in 4 years after fallow or just before fallow (S4 and D4).

Table 1
Cultivation intensity experiment.

Treatment	Snow retention	Fertilization, kg ha^{-1} year^{-1}
Simplified (ST)	No	No
Common (CT)	35 cm	Phosphorus: 20
Intensive (IN)	40 cm	Phosphorus: 20 Nitrogen: 40–50

Table 2
Tillage depth experiment in fallow-wheat cropping.

Rotation	Shallow till (S), cm	Deep till (*D*), cm
Fallow year		
1st year wheat after fallow[a]	12–14	25–27
2nd year wheat after fallow	10–12	20–22
3rd year wheat after fallow	10–12	20–22
4th year wheat after fallow[a]	10–12	20–22

[a] Samples years, bolded: Fallow – **Wheat** – Wheat – Barley – **Wheat**.

This experiment was initiated to study the effect of tillage depth and fallowing on soil properties and CO_2 fluxes (Table 2).

The soils were sampled and examined during 2000–2001 for the experiment no. 1 *cultivation intensity* and 2 *tillage depth*; and during 2012–2013 for the experiment no. 3 *minimum and zero till*. The sampled soil were analysed for soil physical properties, content of soil organic matter (SOM), content of labile fractions of SOM, soil microbial biomass and soil enzymatic activity.

Among proposed treatments the simplified technology (ST) in the cultivation intensity experiment and the shallow till (S) in tillage depth experiment are the least energy-consuming treatments versus intensive and deep tillage treatments. Also, the new soil processing concept such as minimum and zero till (direct planting) technologies was studied in this research.

All analytical and data processing methods were performed by internationally certified methods by using the modern laboratory instruments and apparatus [21–27].

3. Results and discussions

3.1. Soil physical characteristics

Soil water-physical properties influence directly the growth and development of plants. Therefore the regulation of these parameters is one of the most important issues. The dynamics of soil moisture, density and moisture reserves are shown in Table 3.

Comparative analysis of water-physical properties under minimum and zero till systems has shown that under the zero till in 0–50 cm soil layer the average values the soil moisture in spring was 15.89%, soil density was 1.17 g/cm^3; total porosity was 53.6 % and total moisture capacity was 46.1 m^3; while under the minimum till these parameters were: 16.65, 1.25, 49.8 and 40.3, respectively (Table 3).

Table 4 shows that to the end of vegetation season the dynamics of soil water-physical parameters changed. After dry summer soil moisture content was by 2.28% higher and moisture reserves were by 0.8 m^3 greater under the minimum till versus zero till. The soil

Table 3
Water-physical properties in 2013 (*spring*).

Depth, cm	Moisture, %	Density, g/cm^3	Porosity, %	Moisture capacity, m^3
Minimum tillage				
0–10	16.40	1.09	56	51.4
10–20	19.64	1.20	52	43.3
20–30	19.08	1.25	50	40.0
30–40	16.25	1.33	47	35.3
40–50	11.87	1.40	44	31.4
Average	**16.65**	**1.25**	**49.8**	**40.3**
Zero tillage				
0–10	15.63	1.08	57	52.8
10–20	17.38	1.18	53	44.9
20–30	17.67	1.21	52	42.9
30–40	14.12	1.18	53	44.9
40–50	14.63	1.18	53	44.9
Average	**15.89**	**1.17**	**53.6**	**46.1**

Please cite this article in press as: Saljnikov E, et al., Impact of energy saving cultivations on soil parameters in northern Kazakhstan, Energy (2014), http://dx.doi.org/10.1016/j.energy.2014.03.042

Table 4
Water-physical properties in 2013 (*summer*).

Depth, cm	Moisture, %	Density, g/cm^3	Porosity, %	Moisture capacity, m^3
Minimum tillage				
0–10	22.02	1.01	60	59
10–20	20.80	1.15	54	46
20–30	15.82	1.25	50	40
30–40	15.47	1.18	53	44
40–50	15.72	1.18	53	44
Average	**17.97**	**1.15**	**54**	**46.6**
Zero tillage				
0–10	20.87	0.88	65	73
10–20	15.62	1.27	50	39
20–30	14.80	1.18	53	44
30–40	13.77	1.25	50	40
40–50	13.37	1.36	46	33
Average	**15.69**	**1.19**	**52.8**	**45.8**

density and porosity also showed better characteristics under minimum till in summer season, while in spring the soil density, porosity and moisture capacity were more favourable under the zero till system (Tables 3 and 4). These results confirm the hypothesis that under drier conditions (in summer) the minimum tillage is more appropriate for the soil physical conditions.

3.2. Soil organic matter (SOM)

Soil organic matter (SOM) is the most reactive and powerful factor in the formation of soil and its fertility. Over time, the amount of carbon and nitrogen stored changes as a result of climate, geology, vegetation disturbances, changes in land use patterns, and degradability of organic matter in the soil ecosystems [28,29].

Soil resources are exhaustible and finite. Nevertheless, industrial agriculture neglects these resources and soils are exposed to increasing degrees of chemical, physical and biological stress [30]. The cause for soil fertility decline is that most agricultural land use systems imply a net removal of nutrients from the soil either with the harvest and/or through increased losses as compared with natural ecosystem [31,32]. Unless the nutrients removed by the harvested product are replaced either naturally, through weathering and bio-geocycling, or through the use of sustainable agricultural care, many soils will deteriorate under permanent cropping.

3.2.1. Cultivation intensity experiment

Effects of intensity of cultivation on SOM are shown in Table 5. Generally there wasn't statistically significant difference in the content of total SOM between the cultivation intensity treatments. Although CT and IN technologies had a greater plant uptake than ST, total SOM content was unaffected under CT and IN treatments. This is because CT and IT received additional agronomic inputs such as fertilization and snow retention that contributed to the higher biomass and thus plant uptake of soil nutrients. However, higher plant biomass in turn contributes to a greater amount of crop residue returned into the soil, which replenishes the SOM. Therefore under ST the lower crop yield removed fewer nutrients from soil, but input of plant residues also was less. These reasons resulted in absence of a significant difference in the content of total nitrogen and total carbon between the different cropping technologies. It is known that soil organic matter consists of labile (active) and stable (inert) fractions. The inert fraction of SOM in most mineral soil comprises more than 75% and it is hardly subject to changes [39]. Nearly all the soil processes mediated by microorganisms occur within the labile organic matter that is less than 25% of total SOM.

Table 5
Soil organic matter in cultivation intensity experiment

Treatment	Total N, %	Total C, %	Organic C, %
0–10 cm, first year			
Simplified (ST1)	0.25a[a]	3.20a	1.98a
Common (CT1)	0.21a	2.43a	1.90a
Intensive (IN1)	0.22a	2.62a	2.00a
0–10 cm, fourth year			
Simplified (ST4)	0.22a	2.91a	1.92a
Common (CT4)	0.16b	2.54a	2.41a
Intensive (IN4)	0.25a	3.01a	2.41a
10–20 cm, first year			
Simplified (ST1)	0.19a	2.64a	1.66
Common (CT1)	0.18a	2.51a	1.49
Intensive (IN1)	0.19a	2.73a	1.68
10–20 cm, fourth year			
Simplified (ST4)	0.16a	2.66a	1.53
Common (CT4)	0.25a	3.14a	2.21
Intensive (IN4)	0.24a	2.99a	2.26
20–30 cm, first year			
Simplified (ST1)	0.16a	2.70	1.45
Common (CT1)	0.17a	2.53	1.42
Intensive (IN1)	0.16a	2.47	1.46
20–30 cm, fourth year			
Simplified (ST4)	0.15a	2.63	1.28
Common (CT4)	0.16a	2.74	1.61
Intensive (IN4)	0.22a	2.80	1.91

ST – simplified technology, without fertilization and snow retention.
CT – common technology, fertilization (standard doses) and snow retention (35 cm).
IN – intensive technology, fertilization (increased doses), snow retention (40 cm) and herbicides.
[a] Different letters denote the statistically significant difference at $r = 0.657$, $^*P < 0.05$.

3.2.2. Tillage depth experiment

Table 6 demonstrates the tillage management effects on SOM content. There was not a significant difference in the content of SOM between the tillage depths and between the phases of crop-rotation. However, a tendency of reduced amount of SOM in the deep (D1 and D4) than in the shallow subsoil till (S1 and S4) in the 0–10 cm and 10–20 cm layers was observed.

Deep till of soil implies that thicker soil layer is subject to loosening resulting in better aeration that accelerates the microbial activity. The soil microorganisms supported by better oxygen supply faster mineralize SOM to retrieve food and energy.

Table 6
Soil organic matter in tillage experiment.

Treatment	Total N, %	Total C, %	Organic C, %
0–10 cm			
Shallow (S1)	0.23a	2.93a	2.20a
Deep (D1)	0.20a	2.63a	1.84a
Shallow (S4)	0.25a	3.10a	2.56a
Deep (D4)	0.24a	3.07a	2.19a
STDEV	0.022	0.215	0.294
10–20 cm			
Shallow (S1)	0.22a	2.80a	1.98a
Deep (D1)	0.20a	2.73a	1.87a
Shallow (S4)	0.22a	2.78a	2.00a
Deep (D4)	0.23a	2.73a	2.20a
STDEV	0.013	0.036	0.137
20–30 cm			
Shallow (S1)	0.20a	2.77a	1.84a
Deep (D1)	0.19a	2.63a	1.74a
Shallow (S4)	0.21a	2.71a	1.94a
Deep (D4)	0.20a	2.77a	2.02a
STDEV	0.008	0.066	0.122

Please cite this article in press as: Saljnikov E, et al., Impact of energy saving cultivations on soil parameters in northern Kazakhstan, Energy (2014), http://dx.doi.org/10.1016/j.energy.2014.03.042

Table 7
Main soil agrochemical characteristics under minimum and zero tillage systems.

Depth, cm	Organic C, %	Hydrolysable N, mg kg^{-1}	Total N, %
Minimum tillage			
0–10	2.35	11.2	0.168
10–20	2.06	8.4	0.168
20–30	1.77	11.2	0.168
30–40	1.22	5.6	0.098
40–50	0.53	5.6	0.042
Zero tillage			
0–10	2.88	39.2	0.266
10–20	2.65	36.4	0.226
20–30	2.18	33.6	0.238
30–40	2.06	28.0	0.210
40–50	1.88	19.6	0.182

Also, there might be another reason: the permanent shallow till (10–12 cm and 10–14 cm) might cause a formation of compact layer immediately below the plough line. Therefore, penetration of roots below the compacted layer might be restricted and more roots were concentrated above the compacted layer (14 cm). Under arid climatic conditions, whole-plant growth rate, carbon allocation and phenological development can be significantly affected by compaction in the ploughed layer [33–35]. Voorhees et al. [36] also found that compaction is often associated with a decrease in crop yield because it results in restricted movement of water, air and roots. This might result in an increased amount of SOM in the top 14 cm layer.

3.2.3. Minimum and zero till

Table 7 shows the main soil agrochemical characteristics under the minimum and zero tillage systems. The soil humus, total nitrogen and hydrolysable nitrogen content showed significantly higher values under the zero tillage than under minimum tillage.

The amount of hydrolysable N under zero tillage was 3–4 times higher than under the minimum tillage. This is due to the reduced mechanical disturbance of the soil. Under zero tillage nearly all crop residues remain on the top layer of the soil. Then due to higher enzymatic activity (see Section 3.3.4) these plant residues provide greater nutrient source for microorganisms and then to plants, thus improving soil fertility characteristics. According to Coates et al. [45], all types of reduced tillage require significantly less energy input than conventional systems. Other authors also found that, reduced tillage systems maintain less soil compaction and less soil aggregate stability disturbance [46].

3.3. Soil labile organic matter

Soil organic matter is built up of different fractions varying from very active to passive, both chemically and biologically. Labile fraction OM is largely made up of plant debris and is a main source of plant and microorganism nutrients [37,38]. The amount of mineralizable organic matter in soil is an indicator of organic matter quality, because it affects nutrient dynamics within single growing seasons, organic matter content in soil under contrasting management regimes, and carbon sequestration over extended periods of time [39].

3.3.1. Cultivation intensity experiment

3.3.1.1. Potentially mineralizable nitrogen (PMN). Fig. 1 shows the effect of cultivation intensity on mineralizable nitrogen (PMN). There is a significant difference in the amount of PMN in the 0–10 cm soil layer. Simplified technology (ST) maintained the least amount of PMN, while intensive technology treatment (IN) accumulated the greatest amount of PMN. These differences are directly linked to the amount of plant residues left on the field after harvest. Because plant residues are the main source of labile organic matter, i.e. organic matter available for decomposition by microbes, higher primary production directly leads to higher amount of labile OM [19].

The amount of PMN was distributed accordingly to the input of agronomic treatments: IN technology received both nitrogen and phosphorus fertilizer and greater moisture through snow retention; CT technology received only phosphorus fertilizer and less snow retention, while ST technology didn't receive any agronomic inputs. Snow retention maintained greater water storage in the soil depth, which resulted in more favourable conditions both for plant and microorganisms, while together with fertilization they contributed to greater accumulation of plant residues.

So, the increasing cultivation intensity results in better soil conditions for soil microbial activity which returns in accelerated mineralization of SOM. However, further continuous accelerated mineralization of SOM firstly, would results in soil fertility degradation [40–43] and secondly, to the increased CO_2 flux originated from land management.

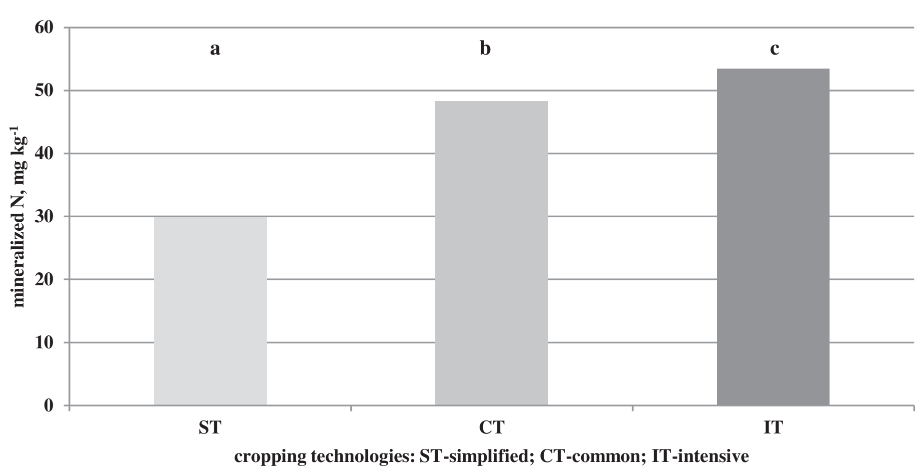

Fig. 1. Nitrogen mineralized in 28-days of laboratory incubation from three different cultivation intensity systems from 0 to 10 cm, where ST-didn't receive any treatments; CT received P-fertilizer, 35-cm snow retention and herbicides; IT received P-and N-fertilizers, 40-cm snow retention and herbicides. †Different letters denote the statistically significant difference, r^{***} at $P < 0.05$.

Please cite this article in press as: Saljnikov E, et al., Impact of energy saving cultivations on soil parameters in northern Kazakhstan, Energy (2014), http://dx.doi.org/10.1016/j.energy.2014.03.042

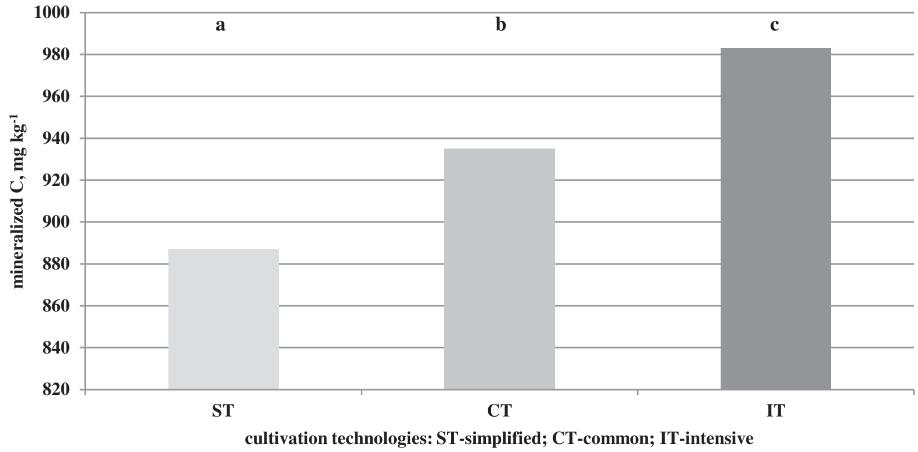

Fig. 2. Carbon mineralized in 28-days of laboratory incubation from three different cultivation intensity systems from 0 to 10 cm, where ST-didn't receive any treatments; CT received P-fertilizer, 35-cm snow retention and herbicides; IT received P-and N-fertilizers, 40-cm snow retention and herbicides. †Different letter indicates significant difference between the systems at $P < 0.01$.

3.3.1.2. Potentially mineralizable carbon (PMC). Fig. 2 demonstrates how soil C mineralization followed similar trend as N being the lowest under the ST and the highest under the IT technologies, what is explained by the increased microbial activity under higher intensity energy input, which resulted in increased mineralization of organic C.

3.3.2. Tillage depth experiment

Table 8 presents the amount of labile N (PMN) in tillage depth experiment. Tillage at two different depths greatly affected the accumulation of PMN. Shallow tilling (S1 and S4) maintained significantly greater amount of labile N than deep till (D1 and D4), in both phases of the crop-rotation (Table 8). This big difference is most probably attributed to the degree of physical disturbance. Under the shallow till (10–14 cm) upper layer is tilled more intensively, than under the deep till (25–27 cm). As long as most of SOM concentrated in upper 0–10 cm layer [18], the disturbance of this layer accelerates the microbial activity leading to the increased mineralization of SOM. Mineralization of SOM under the deep till appears to be less than under shallow till.

Shallow till in 4th year maintained the highest amount of PMN, due to the greater accumulation of crop residues during 4 years of cropping after bare-fallowing, while the soil directly after fallow had less crop residues due to their depletion during the fallow year.

The soil labile organic matter directly indicates the ability of a given soil to supply plants with nutrients. The more PMN means the higher nutrient reserves [22]. Thus, shallow tillage technology showed 3.3 times greater PMN under the S1, and 8.6 times greater under the S4 treatments than D1 and D4 treatments, respectively (Table 8).

The results show that shallow subsoil till better supports microbial activity leading to higher production of plant nutrients and saving energy.

Table 8
Potentially mineralizable nitrogen (PMN) in tillage depth treatments.

	PMN, mg kg^{-1} dry soil		
	0–10 cm	10–20 cm	20–30 cm
Shallow till, 10–14 cm (S1)	36.85a†	3.98a	2.70a
Deep till, 20–27 cm (D1)	11.15b	2.98a	2.27a
Shallow till, 10–14 cm (S4)	46.82c	6.61b	4.50b
Deep till, 20–27 cm (D4)	5.45d	5.82b	3.87b

†Different letters denote the statistically significant difference $r = ^{***}$, at $P < 0.05$.

3.3.3. Soil microbial characteristics under minimum and zero tillage

Soil microorganisms are one of the most important indicators of soil health. Bacteria, actinomycetes and fungus play an important role in decomposing organic matter degrading cellulose, forming antibiotic substances, in humus formation, etc. Table 9 represents quantity and quality of microorganisms in minimum and zero till systems. In both treatments bacteria composites the most part of the microbial biomass. Both tillage systems showed favourable conditions for microbial growth, with a little dominance in number of microorganisms under the minimum tillage. The results showed that both tillage systems are favourable in terms of microbiological growth.

3.3.4. Enzymatic activity

Recently, soil enzymology has been attracting big attention of scientists. Enzymatic activity appeared to be more sensitive and stable indicator of soil biological activity than the intensity of microbiological processes. The transformation of organic substances, mobilization of plant nutrients in soil is mediated by enzymes both exuding by living organisms and from adsorbed state. Higher enzymatic activity in soil means better biological indices of the soil. The minimization of soil tillage generally positively influenced the soil's enzymatic activity.

The urease and peroxidise activity were higher under the zero till. And in both cases their activity increased with depth (Table 10). The catalase activity didn't show changes with depth, but under the zero till the catalase activity was less than under the minimum till. The high peroxidise and urease activity implies high rates of mineralization processes in soil, indicating that under zero tillage the mineralization processes are more active. Catalase activity was more homogenously distributed along soil depth under zero till

Table 9
Number of microorganisms under minimum and zero tillage systems.

Tillage system	Depth, cm	Million/g soil		Thousand/g soil
		Bacteria	Actinomycetes	Fungus
Minimum tillage	0–10	4.8	2.6	3.7
	10–20	4.2	2.5	2.9
	20–30	2.2	2.3	2.0
Zero tillage	0–10	4.0	2.9	3.9
	10–20	3.3	2.6	3.0
	20–30	2.0	2.0	2.1

Please cite this article in press as: Saljnikov E, et al., Impact of energy saving cultivations on soil parameters in northern Kazakhstan, Energy (2014), http://dx.doi.org/10.1016/j.energy.2014.03.042

Table 10
Enzymatic activity in southern Chernozem, average for 2013.

Depth, cm	Enzymes		
	Urease	Catalase	Peroxidise
Minimum tillage			
0–10	2.3 ± 0.1	0.82 ± 0.1	10.2 ± 0.1
10–20	4.1 ± 0.1	0.78 ± 0.1	10.5 ± 0.2
20–30	8.5 ± 0.1	0.89 ± 0.1	12.6 ± 0.1
30–40	11.9 ± 0.2	0.85 ± 0.1	13.4 ± 0.3
Zero tillage			
0–10	4.2 ± 0.1	0.71 ± 0.1	12.3 ± 0.1
10–20	6.3 ± 0.1	0.75 ± 0.1	13.1 ± 0.1
20–30	9.6 ± 0.1	0.69 ± 0.1	14.2 ± 0.1
30–40	14.1 ± 0.12	0.67 ± 0.1	14.2 ± 0.1

indicating on even distribution of oxygen in plough layer under zero till.

Dynamic soil characteristics such as mineralizable N, microbial biomass and enzymatic activity respond more rapidly and strongly to crop management changes than do characteristics such as total soil organic matter [44].

4. Conclusions

The results of the study showed that total soil organic matter can't serve as indicator of soil fertility changes under different intensity soil tillage. Only zero till showed significant difference in the content of SOM implying that total SOM content is changed under any soil tillage intensity, and only elimination of tillage can maintain SOM content at higher level.

Zero or minimum till save energy and improve the qualities of the soil for agricultural purposes because minimization of mechanical disturbance of the soil improves its structure. Microorganisms are less disturbed under reduced tillage and have higher biological activity.

Under minimum and zero till the natural mulch on the surface preserves moisture and protects against soil erosion from both water and wind.

Minimum and zero till are useful in the continental climate of northern Kazakhstan. The proposed cropping technologies are shown to be effective in the climate of dry hot summers and long cold winters. And they have proved effective to improve water and soil conditions while saving energy. Carbon dioxide emissions due to agricultural activities were significantly less under minimum soil disturbance.

The results of this work contributed to better understanding of the changes in soil biological characteristics under less intensive soil cultivation (less energy input). However, further studies need to be conducted for better integration of reduced energy input technologies with crop production, which will appropriately fit the environment and at the same time satisfy farmers' interest.

Acknowledgements

This study was completed under the support of Sumitomo Foundation, Japan (1999–2000); Ministry of Science and Education of the Republic of Kazakhstan 2012–2015 (Grant no. 187), and the Ministry of Education, Science and Technological Development, Serbia 2011–2014 (project TR 37006).

References

[1] Dyer JA, Baier W, Hayhoe HN, Fisher G. Spring field work day probabilities for selected sites across Canada. Technical Bull 1978;86:93.
[2] Pelizzi G, Cavalchini A, Lazzari M. Energy in agricultural machinery and mechanization.. London, New York: Elsevier Appl Sci; 1988.
[3] Bertocco M, Basso B, Sartori L, Martin EC. Evaluating energy efficiency of site-specific tillage in maize in NE Italy. Biores Tech 2008;99:6957–65.
[4] Alhajj Ali S, Tedone L, Mastro G. A comparison of the energy consumption of rainfed durum wheat under different management scenarios in southern Italy. Energy 2013;61:308–18.
[5] Tabatabaeefar A, Emamzadeh H, Ghasemi M, Varnamkhasti Rahimizadeh R, Karimi M. Comparison of energy of tillage systems in wheat production. Energy 2009;34:41–5.
[6] Chesnyak GYA. Changes of humus quantity and quality and the ways of providing of positive humus balance in Typical Chernozems of Ukraine under intensive agricultural use. In: Proc VI Meeting of Soil Science Society of USSR2; 1981. pp. 42–3.
[7] Anderson DW, Joug E, Verity GE, Gregorich EG. The effect of cultivation on the organic matter of soils of the Canada prairies. In: Transact. 13 Cong. ISSS, Hamburg, 13–20 Aug., vol. 4; 1986. pp. 1344–5.
[8] Mileusnic ZI, Petrovic DV, Djevic MS. Comparison of tillage systems according to fuel consumption. Energy 2010;35:221–8.
[9] Lal R. Residue management, conservation tillage and soil restoration for mitigating greenhouse effect by CO_2-enrichment. Soil Till Res 1997;43:81–107.
[10] Tilman D, Cassman KG, Matson PA, Naylor R, Polasky S. Agricultural sustainability and intensive production practices. Nature 2002;48:671–7.
[11] Cole CV. Agricultural options for mitigation of greenhouse gas emissions. In: Climate change: impacts, adaptation and mitigation of climate change: scientific technical analyses. intergovernmental panel on climate change, Working Group II. Cambridge, UK: Cambridge University Press; 1996.
[12] Cole CV, Duxbury J, Freney J, Heinemeyer O, Minami K, Mosier A, Paustian K, Rosenberg N, Sampson N, Sauerbeck D, Zhao Q. Global estimates of potential mitigation of greenhouse gas emissions by agriculture. Nutr Cycl Agroecosys 1997;49:221–8.
[13] Schlesinger WH. Carbon sequestration in soils. Science 1999;284:95.
[14] Börjesson P II . Energy analysis of biomass production and transportation. Biomass Bioenergy 1996;11:305–18.
[15] Robertson GP, Paul EA, Harwood RR. Greenhouse gases in intensive agriculture: contributions of individual gases to radiative forcing of the atmosphere. Science 2000;289:1922–5.
[16] Kern S, Johnson MG. Conservation tillage impacts on national soil and atmospheric carbon levels. Soil Sci Soc Am J 1993;57:200–21.
[17] Ismail I, Blevins RL, Frye WW. Long-term no-tillage effects on soil properties and continuous corn yields. Soil Sci Soc Am J 1994;58:193–8.
[18] Coûteaux MM, Bottner P, Berg B. Litter decomposition, climate and litter quality. Tree 1995;10:63–6.
[19] Saljnikov-Karbozova E, Funakawa S, Akhmetov K, Kosaki T. Soil organic matter status of Mollisols soil in North Kazakhstan: effects of summer fallow. Soil Biol Biochem 2004;36:1373–81.
[20] Soil Survey Staff. Soil taxonomy. 2nd ed. Washington, DC: USDA; 1999.
[21] Sumner ME, Miller WP. Cation exchange capacity and exchange coefficients. In: Methods of soil analysis, part 3, chemical methods. Madison: Wisconsin; 1996. pp. 1201–29.
[22] Nelson DW, Sommers LE. Total carbon, organic carbon, and organic matter. In: Methods of soil analysis, part 3, chemical methods; 1996. pp. 961–1010. Madison, WI.
[23] Keeney DR, Nelson DW. Nitrogen-inorganic forms. In: Page AL, editor. Methods of soil analysis. Part 2. Agronomy, monograph 9. 2nd ed. ASA, SSSA; 1982. p.643–98.
[24] Inc SPSS. Sigma plot. Chicago, IL: SPW10, Statistics; 2010.
[25] Zak JC, Willig MR, Moorhead DL, Wildman HG. Functional diversity of microbial communities: a quantitative approach. Soil Biol Biochem 1994;26:1101–8.
[26] Bach AN, Oparin AI, Wahner R. Studies on the enzyme content of ripening, dormant and germinating wheat grains. Biochem Z 1927;180:363.
[27] SPSS Inc. SYSTAT version 8.0. Chicago, IL: Statistics; 1998.
[28] Moshin Ali M, Saheed SM, Kubota D, Masunaga T, Wakatsuki T. Soil degradation during the period 1967–1995 in Bangladesh, I. Carbon and nitrogen. Soil Sci Plant Nutr 1997;43(4):863–78.
[29] Hartemink AE. Soil fertility decline in some major soil groupings under permanent cropping in Tanga region, Tanzania. Geoderma 1997;75:215–29.
[30] Greenland DJ, Szabolcs I. Soil resilience and sustainable land use. Wallingford, Oxon, UK: CABI; 1994. p. 576.
[31] Rasmussen PE, Allmaras RR, Rohde RR, Roager NC. Crop residue influences on soil carbon and nitrogen in a wheat-fallow system. Soil Sci Soc Am J 1980;44:596–600.
[32] Gregorich EG, Janzen HH. Decomposition. In: Sumner ME, editor. Handbook of soil science; 2000. C107–20.
[33] Abu-Hamdeh Nidal H. Soil compaction and root distribution for okra as affected by tillage and vehicle parameters. Soil Till Res 2003;74:25–35.
[34] Chen G, Weil RR. Root growth and yield of maize as affected by soil compaction and cover crops. Soil Till Res 2011;117:17–27.
[35] Rosolem CA, Foloni JSS, Tiritan CS. Root growth and nutrient accumulation in cover crops as affected by soil compaction. Soil Till Res 2002;65:109–15.
[36] Voorhees WB, Nelson WW, Randall GW. Extent and persistence of subsoil compaction caused by heavy axle loads. Soil Sci Soc Am J 1986;50:428–33.
[37] Dalal RS, Mayer RJ. Long-term trends in fertility of soil under continuous cultivation and cereal cropping in Southern Queensland. II Total organic carbon and its rate of loss from soil profile. Aust J Soil Res. 1986;24:281–92.
[38] Janzen HH, Campbell CA, Brandt SA, LaFond GP, Townley-Smith L. Light-fraction organic matter in soils from long-term crop rotations. Soil Sci Soc Am J 1992;56:1799–806.

[39] Gregorich EG, Carter MR, Angers DA, Monreal CM, Ellert BH. Towards a minimum data set to access soil organic matter quality in agricultural soils. Can J Soil Sci 1994;74:367–85.
[40] Bird MI, Chivas AR, Head J. A latitudinal gradient in carbon turnover times in forest soils. Nature 1996;381:143–6.
[41] Christensen BT. Carbon in primary and secondary organo-mineral complexes. Adv. Soil Sci. 1996;24:97–165.
[42] Amelung W, Flach KW, Zech W. Climatic effects on soil organic matter composition in the Great Plains. Soil Sci Soc Am J 1998;61:115–23.
[43] Trumbore SE, Chadwick OA, Amundson R. Rapid exchange between soil carbon and atmospheric carbon dioxide driven by temperature change. Science 1996;272:393–6.
[44] Sparling GP. Ratio of microbial biomass to soil organic carbon as a sensitive indicator of changes in soil organic matter. Aust J Soil Res 1992;30:195–207.
[45] Coates W, Thacker G. Reduced tillage systems for irrigation cotton: energy requirements and crop response. Appl Eng Agric 1997;13(1):31–4.
[46] Mari GR, Changyine J. Energy analysis of various tillage and fertilizer treatments on corn production. Am Euras J Agric Environ Sci 2007;2(5):486–97.

Please cite this article in press as: Saljnikov E, et al., Impact of energy saving cultivations on soil parameters in northern Kazakhstan, Energy (2014), http://dx.doi.org/10.1016/j.energy.2014.03.042