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UABIO
Біоенергетична асоціація України

Report of the workshop "Agricultural residues for bioenergy. Problems and solutions"

27 September 2018, Kiev

Authors: Jan Peter Lesschen, Tetiana Zheliezna, Wolter Elbersen, Kees Kwant

With the input from: Oleksandra Tryboi, Yuri Kryvda, Francisco J. Arriaga, Nicolae Scarlat, Mykola Royik, Sandra Corsi, Luigi Pari

1 Introduction

1.1 Background

In Ukraine, crop residues are more and more being used as biomass for heat production to decrease the use of imported natural gas. To become less dependent on natural gas for heating, bioenergy offers a great opportunity for Ukraine with its huge agricultural base. After wood residues, agricultural residues are increasingly being mobilized to provide energy for heating systems. This has led to the conversion of natural gas fired boilers for local heating, into biomass boilers. The feedstock consists of locally sourced biomass such as processing residues. Increasingly also field residues are being collected and used. Also in other countries there is a shift to using crop residues for bioenergy production, as food crop based biofuels will no longer be supported.

This is leading to concerns about the effect of removing crop residues on soil quality. There is quite some discussion about the amount of residues that can be extracted from the field, while conserving soil carbon and soil fertility, as crop residues are often the main source of carbon input to the soil.

However, most farmers are not much interested in using straw to maintain soil organic matter, and often, although officially not allowed, still burn the crop residues in the field. This lack of interest can be explained. Straw in the field is a nuisance during ploughing and seeding of a following crop and may increase disease pressure. In addition straw can immobilize nutrients when ploughed under, which can potentially lower the yield of the following crop. The benefit of maintaining soil organic matter and soil nutrients is mainly relevant in the long term, and of little value to a farmer leasing land for short periods of a few years. Removal of straw would be less of a problem if fertilisation rates were adequate and yields were much higher than they are now and if manure or other organic fertilizer were applied. Actually, the yield gaps for wheat and corn are close to 60% in Ukraine, meaning that current yield are 40% of potential rainfed yields (www.yieldgap.org).

The famous Chernozem soils of Ukraine have been formed over thousands of years under a grassland vegetation with relatively low rainfall. Since the fall of the Soviet Union the use of fertilizers, both chemical and manure, has decreased, contributing to a lowering of soil carbon and nutrient contents of the soil and therefore the productivity of the soil. In Ukraine, harvesting crop residues comes at a cost to soil quality but it can also reduce the cost of natural gas imports, increase energy security and save a lot of money and reduce GHG emissions. It may however be possible to use the money saved by using crop residues instead of natural gas to take measures that maintain soil quality. Would this still make using crop residues attractive?

To explore this issue, an expert workshop was organised on September 27th, 2018 in Kiev, Ukraine. Experts on soil fertility, soil carbon and bioenergy presented their research and discussed with the public on recommendations and research questions that need to be further explored.

1.2 Objective

The objective of the workshop was to assess the status of the knowledge and practice on soil quality in relation to using crop residues in Ukraine and, to define knowledge gaps to effectively harmonize using crop residues while maintaining soil quality. The findings should be used to help develop recommendations and policies for using crop residues for energy and other biobased applications and formulate further research proposals.

The workshop aimed to highlight the issue of using agricultural residues for energy in relation to soil quality and fertility and to define research priorities to harmonize soil quality maintenance with using crop residues for energy and other purposes.

1.3 Workshop organisation

The workshop was organized by the Partners for International Business project: Biobased Energy Ukraine, the Embassy of the Kingdom of the Netherlands in Ukraine, State Agency for Energy Efficiency and Energy Saving of Ukraine (SAEE) and Bioenergy Association of Ukraine (UABio). The Dutch Partners for International Business project on Biobased Energy in Ukraine work with a set of partners from industry and research to highlight this issue and is engaged to contribute to find solutions. They find that energy independence should not and may not need to result in reduction of soil quality in Ukraine. The full programme of the workshop can be found in Annex 1.

2 Summary of the expert presentations

2.1 The state of fertility of soils in Ukraine

Yuri Kryvda (Soils Protection Institute of Ukraine)

In Ukraine over the 50 last years, the agrochemical certification (inspection) of agricultural lands was performed every 5 years. So far, results from 10 certification rounds are available by now, the current (11^{th}) being in progress since 2016 until 2020. Results of the inspections show that in general, the average content of organic matter in the soils of Ukraine decreased from 3.36% in 1986-1990 to 3.17% in 2011-2015, although a slight increase from 3.14% to 3.17% was observed between the 9^{th} and 10^{th} certification rounds. For soil acidity, Ukraine's soils are divided mainly into 37% of neutral soils, 20% of nearly neutral soils, 16% of sub-alkali soils and 12% of sub-acid soils. The dynamics of humus balance in Ukraine's soils in 2007-2017 was negative ranging from -0.53 t/ha in 2010 to -0.13 t/ha in 2013 and 2015, and being -0.25 t/ha in 2017. The dynamics of balance of nutrients (N, P, K) was also negative during that period, although the amount of mineral fertilizers by agricultural enterprises increased during that period of time from 51 kg/ha in 2007 to 110 kg/ha in 2017. The introduction of organic fertilizers has dropped dramatically since 1990 being now about 0.5 t/ha. The figure reflects the current capability of Ukrainian animal husbandry (that is the amount of available manure) and is considered very insufficient for the needs of Ukrainian crop production. On the whole, the area of fields where straw is used as fertilizer (including straw along with nitrogen fertilizers) has been rising since 2007. As the grain of wheat, maize and other crops takes out of soil a lot of nutrients (N, P, K), their loss should be compensated by crop residues and fertilizers. The minimal amount of straw and fertilizers that ought to be introduced in order to preserve the humus content is 100% for straw without any fertilizers, 70% of straw + 45 kg NPK, 60% of straw + 90 kg NPK, 50% of straw + 4.5 t/ha of manure + 23 kg N 34 kg P and 18 kg K, 30% of straw + 9 t/ha of manure + 45 kg N, 68 kg P and 36 kg K. He concluded with the key tasks aimed at the preservation and increase of soil fertility, which are (among others): to slow down the decrease in humus content, to achieve a self-supporting balance of humus, to enrich the soil with nutrients, to systemize the available information on soil fertility, to elaborate the economic mechanism to finance measures targeted to preserve and increase the soil fertility.

2.2 Research in the USA on sustainable use of crop residues for energy

Francisco J. Arriaga (University of Wisconsin-Madison, USA)

In the US, the main interest on the use of crop residues for energy production has been for liquid fuels to replace petroleum dependence. Mainly bioethanol is produced, first from maize grain, but since a few years the use of maize stover has become important. Several studies have been conducted to assess the effects of using residues on crop productivity and soil health. Results showed that there was no negative effect on crop yield when residues were harvested, and even increases were observed in soils with high organic matter contents (Mollisols). Zero tillage had at moderate stover harvest level a slight negative effect on crop yield, whereas at high stover harvest level yield was higher. Crop yield can increase when stover is removed, as otherwise the residues will fix part of the mineral nitrogen that is applied, as the CN ratio of stover is high. As removal of crop residues increases the risk of erosion, accompanying measures such as cover crops or no till are recommended. Reducing row spacing in maize (from 76 to 38 cm) can also reduce surface runoff and prevent negative effects on crop yields. Results were presented on sustainable harvest rates at regional level for the US, based on inventory data of local soil and crop factors. He concluded that crop residue harvest could be done with minor impacts to soil and environment when done properly, e.g. use of cover crops, reduced tillage and replacement crop nutrients. Good data and model implementation is key for making informed decisions on the use of crop residues.

2.3 Experience in the EU with sustainable use of crop residues for energy

Nicolae Scarlat (JRC, Italy)

The use of bioenergy is increasing and crop residues form a significant part of the biomass potential. A spatially explicit assessment of sustainable crop residues potential in Europe was presented, based on statistical data sets and modelling. First, a theoretical crop residue potential was calculated based on crop production and residue to grain ratios, second a technical potential was calculated based on the amount that can actually be harvested. Next, the environmental potential was calculated, using an agroecosystem model (Century) calculating sustainable removal rates. Finally, a sustainable potential was calculated, based on the technical and environmental potential, and taking constraints for mobilisation into account. A significant annual variation in crop residue potential was found, due to differences in crop yields over the years.

Three scenarios were assessed, no crop residue removal, 50% removal and 100% crop removal, where in the 100% removal scenario negative soil carbon balances are occurring almost everywhere, whereas in the no removal scenario SOC balances are positive. The technical potential for the EU is about 57% (168 Mton) of the theoretical potential and the sustainable potential is about 40% (124 Mton) of the theoretical potential. A map of potential plant locations was presented, the locations depend on available crop residue resources and collection costs. Main conclusion was that spatially explicit assessment is essential for accurate resource evaluation, considering local conditions.

2.4 Agricultural residues for bioenergy. Problems and solutions

Jan Peter Lesschen (Wageningen University and Research, The Netherlands)

The presentation consisted of two parts, first a modelling study at EU level on the amount of straw that can be harvested without reducing the soil carbon stock was presented, followed by an exploratory model study to assess the effectiveness of options to reduce negative effects of crop residue removal.

For the EU level study a modelling approach was used, in which the environmental impact assessment model MITERRA-Europe was linked to the soil carbon model Roth C. Based on statistical data and relations between crop yield and crop residues, the potential amount of crop residues was determined. Based on the current soil organic carbon stock, which was derived from the LUCAS survey, and data on climate, crop residue and manure inputs, the soil carbon balance was calculated. Results show that the sustainable removal rate ranges from 0 to 100%, depending on crop yield, soil and climate conditions. The total sustainable potential of straw for bioenergy in the EU is estimated at 60-70 Mton.

The other part focused on the assessment of different options to reduce potential negative effects on soil carbon due to crop residue removal. The RothC model was used for two locations in Ukraine with different soil types. The following options were included: use maize instead of wheat straw, harvest every two years, use of no tillage and increase crop yield. Results show that these options reduce the negative soil carbon balance and some can even increase soil carbon stocks when residues are removed, especially the option of no tillage seems promising for Ukraine.

The following recommendations were presented:

1. Sustainable crop residue removal rates should be determined region and farm specific
2. Strategies to reduce potential negative effects on soil quality need to be further quantified (both from soil quality as economic perspective)
3. Long term soil carbon monitoring experiments are required to validate the effectiveness of these strategies

2.5 Using residues vs using biomass crops for energy

Mykola Royik (Institute of bioenergy crops and sugar beet of NAAS, Ukraine)

Mykola Royik made a presentation on “Environmental aspects of growing energy crops and using harvest residues for biofuel”. The speaker informed that Ukraine had joined the Global Soil Partnership and taken a

number of voluntary obligations including the minimization of soil erosion, increase in the content of organic soil matter, ensuring nutrient balance and cycles in the soil and some other obligations. According to the speaker, soils are degrading in Ukraine, and one of the indicators of this process is the loss of humus and nutrients on 43% of arable land area. Agricultural land includes 24 million ha of productive land and 8 million ha of low-yield (sometimes even marginal) land. The latter can be used for growing energy crops, which is the right alternative to using crop residues for energy.
Since 1990, the introduction of organic fertilizer has dropped dramatically in Ukraine, from the average 10 t/ha to 0.5 t/ha. During this period of time, soil acidity has increased by 14%, and the more acid the soil is the more fertilizers it requires. If one takes 17.7 Mt/yr of straw from the fields (according to recommendation of the Bioenergy Association of Ukraine), one must compensate the loss of nutrients by introducing 1.5 Mt/yr of mineral fertilizers. The annual cost of the fertilizers is assessed as 11.4 billion UAH, which is enough to create every year a Miscanthus plantation of 163,000 ha. Growing energy crops results in increasing content of organic matter in soil.
Mr. Royik believes that we can use some amount of crop residues for energy only when a positive humus balance is achieved. At present, it is impossible to take any harvest residues from the fields for energy purposes. We should think not about the current benefit but about the perspective impact. The related motto must be “What is not ecological is not economical!”

2.6 Recommendation from FAO on using agri-residues – Is Ukraine different?

Sandra Corsi (Food and Agriculture Organization of the United Nations (FAO), Italy)

This presentation from the FAO focussed on crop residue management to sustain soil productivity. Conservation agriculture is a combination of practices, including less intensive tillage, permanent soil cover and diverse crop rotations. Ukraine has on average soils from a very good origin with relatively high organic matter contents and good bulk density. These Chernozem soils would in theory offer good potential for no-till systems. However, in Ukraine the use of no-till is so far very limited, probably due to lack of investments and maintaining traditional practices. Soil erosion is a serious issue in Ukraine, with an average erosion rate of 15 ton/ha/year and annual loss of nutrients with a value estimated at 5 billion US dollar. One of the main benefits no tillage and leaving (part of the) crop residues at the surface is the improved infiltration. And for countries where a lot of snow is falling in the winter, like in Ukraine, the remaining stubble improves infiltration. This additional amount of water can be very important to maintain crop yields in dry years, which is important for countries with high yield volatility, like in Ukraine.
The role of research is to come from broad principles to specific recommendations (differentiating to crop and regions) on the amount of crop residue that should be retained, to assess the return on the investments of the different agronomic practices and to investigate what are the behavioural changes that need to take place to improve crop residue management. To reconcile short-term priorities (such as good revenues) with long-term investments (in soil quality) requires coherent policy incentives that ensure sufficient investments in integrated multidisciplinary research.

2.7 Options for harvesting straw of higher quality while leaving more nutrients behind

Luigi Pari (CREA, Italy)

Luigi Pari presented possible technical harvesting measures to reduce impacts of crop residue removal, which were tested in case studies for wheat in Sweden and France. Traditional combines have a threshing system that separates the grains and chaff from the straw, where straw and chaff fall through, whereas the straw is carried onto the straw walkers. New hybrid combines have a tangential threshing system and the ROTO PLUS residual grain separation system, which replaces the straw walker. The two counter rotating rotors generate centrifugal force to separate the remaining grains from the straw and at the same time also detach the fine parts of the straw. The main benefit for the farmer is that the hybrid combine works much faster, but the straw is shorter and more difficult to bail. More of the straw, especially the smaller parts (leaves) that have most nutrients remain on the field. Field measurements in Sweden and France showed that total dry biomass was 14-15 ton/ha, of which 44-51% was grain, 12% chaff and 37-44% straw. Harvest tests showed that with the hybrid combine after baling about 50% of the residues (straw and chaff) were left, whereas with the traditional combine only 20% was left. This increased amount of residue that is left on the field by the hybrid combine could be a way to balance the impact of residue removal. Further research is needed to verify that the part left in the field would be the richest in minerals and nutrients to eventually take actions for adjusting the machines to reach this purpose.

3 Summary of the discussions

3.1 Plenary discussion

After the presentations, a discussion session was organised. First three representatives of the agro holdings, the financial sector and the bioenergy association gave their reactions on the subject and presentation.

The representative from the agro-sector was happy to see the availability of new techniques and management options to increase soil quality and make use of crop residues. They were missing show cases and success stories, which are required to increase the uptake of such measures. Also the economic aspect is important, and currently the use of crop residues would not pay off and should not receive specific support from the government. Another person shortly presented pyrolysis of crop residues and return of biochar to the soil as an alternative. The efficiency of pyrolysis is higher compared to conventional combustion.

As a representative from the financial sector, someone from the EBRD, appreciated the presentations and to hear the different views on the subject. The EBRD works in the bioenergy sector and supports these kind of activities, although most projects are currently focussed on biogas from sugar beet waste and poultry and pig manure. EU funds might be used to have showcases and success stories to learn from. EBRD is an institute for profit but is concerned about sustainability in general and also the issue about soil quality. Therefore no support would be offered for bioenergy project that compete with food production, and for future projects companies should demonstrate that the maintain soil fertility. Some funding might be available for feasibility studies to assess which options might be most promising/sustainable on type of feedstock and way of processing.

The representatives of the Bioenergy Association of Ukraine are in favour of using crop residues for bioenergy. They do not have the objective to use all, but recommend to use about 30% of the residues, which is in line with outcomes from studies in other countries. The current soil fertility decline so far cannot be related to bioenergy, as there is hardly any use straw for bioenergy yet, so the decline is due to other causes. Also field burning is still occurring, so better use this in the boilers. With the income from straw fertilizers can be bought. An option would be to remove residues once every 3 years, but also focussing on areas where high yields are obtained and leaving all residues in areas with low yields might be a good strategy. Straw is not a suitable fuel for wood boilers, but for medium and high capacity boilers straw would be good fuel where there is no need to make pellets but use directly the bales, no need for further processing.

After this plenary discussion, the presenters and the public were divided in three groups that all addressed the following questions:

- Do we agree that agricultural field residues can be removed for other uses?
- How much? Which percentage?
- What determines the fraction that can be removed?
- Is it clear how to do this? Are there questions?
- What research needs to be done to solve the remaining questions?
- Who can carry out this research? What project do we need?

3.2 Summary of discussion in group 1

(9 persons, moderated by Georgii Geletukha, Head of Board at the Bioenergy Association of Ukraine – UABio)

Can crop residues be taken from fields and used for energy?

Yes, but considering some general and local conditions.

How much crop residues can be taken from the fields and used, and what determines the share?

It is known that the official position of the National Academy of Agrarian Sciences of Ukraine is that 20% of the crop residues can be used for energy. Based on this we consider that in general and on average 20-30% of the residues can be taken for other uses. The figures should be carefully specified for each concrete field and crop as in a concrete case they can be considerably higher or lower. A number of special measures such as the use of cover crops, introduction of manure, digestate and other organic fertilizers, application of ash after burning of crop residues may increase the share. In addition, actual crop rotation patterns, higher yields of agricultural crops and other similar factors also can lead to higher shares of residues that can be taken from the field and used.

What studies are required?

The following issues require additional studies: How to collect and bale corn stalks? (Ukraine does not have experience in this area); What is the best approach from technical and economic points of view for harvesting sunflower residues? (collection, comminution, transportation); What are the best crop rotation patterns? (to determine crop rotation patterns that do not exhaust soil). Implementation of a long-term scientific project could help to obtain answers to a number of important questions. The project contents may be as follows: the field under an agricultural crop is divided into two parts. Crop residues from the first part are used for biogas production, and the digestate is put back on the field. Straw from the second part is burnt, and ash is introduced back on the field. Main indicators of the soil quality on the two parts are monitored and compared.

Who can conduct the studies?

The studies can be conducted by research institutes on their test plots of land or on plots of land, which are owned by interested agricultural companies.

3.3 Summary of discussion in group 2

(8 persons, moderated by Kees Kwant, senior bioenergy expert, RVO, The Netherlands)

Can crop residues be taken from fields and used for energy?

At the table, there was agreement that some amount of crop residues can be removed for bioenergy purposes

How much can be removed?

The group first discussed the sheet from the presentation of Yuri Kryvda that showed the minimum amount of crop residues that must be left on the field to conserve humus. Although the participants liked the approach, there was discussion on the values, as the current values were for a fertile soil (Chernozem), which is not a reference for whole of Ukraine. Such an approach should be further elaborated based on different soil types and crops, or maintaining the humus balance as alternative approach. The group agreed that at least the amount of nutrients that are removed with the harvest (as well as crop residues) should be replaced. Ukraine has quite a lot of good fertile soils that are high in organic matter, under arable agriculture it will be difficult to keep soil carbon at this level. The long-term soil fertility is not always maintained because of land ownership issues, as land is often rented for short periods, farmers do not care about the soil and do not improve its quality. Legislation to maintain soil fertility would help to prevent further depletion of the soils. Less intensive tillage could also help, in Ukraine the tillage rate and depth has gone down due to lack of fuel. Also the use of strip tillage (only in the part where is seeded) was suggested, which seems very effective as was also in soils with low organic matter in the US.

What kind of research is required?

First of all, further research on improving fertilizer recommendations is required to stop the current decline in soil fertility. Research on the use of crop residues should focus on testing of practices that can offset potential negative impact on soil carbon. For example a specific technology, such as no tillage or precision agriculture, could be tested with a group of farmers, which can be scaled up in the official programs on resources use efficiency. There was discussion in the group whether the research should start small scale with a few farmers in one region, or have a larger project directly looking at different regions in Ukraine. Show case farms for different regions which have different soils and different crop rotations are needed.

How to organise this?

This could be formulated in a EU proposal that will look at different regions and different crops, also new crops should be included. Research should focus on the options to test new practices to maintain soil fertility, which should also be oriented at application in practice, with pilot / showcase farms.

3.4 Summary of discussion in group 3

(8 persons, moderated by Tetiana Zheliezna, an expert at the Bioenergy Association of Ukraine – UABio)

Can crop residues be taken from fields and used for energy?

Speaking as a whole for the current situation in Ukraine, 4 persons answered in the negative, and 4 persons answered in the positive.

How much crop residues can be taken from the fields and used, and what determines the share?

Halve of the group would not recommend any average percentage for Ukraine as a whole, whereas the other halve suggested some average percentages for Ukraine as a whole based on UABio's recommendations, which are that 30-40% of crop residues (depending on a crop type) can be taken and used. Everyone agreed that in practice, the share of agricultural residues that can be taken and used for energy should be determined for each concrete field. The percentage depends on the actual state of soil and time history (dynamics) of the relevant indicators (the content of organic matter and some other indicators). In concrete cases, the share can vary from 0% to 100%.

What studies are required?

In Ukraine, quite a large number of relevant studies of many years have been done and huge amount of results have been obtained. One of the rational tasks may be to analyze, compare and generalize the available results on the new quality level in order to identify what is already known and what is still missing. Some suggestions as for additional required studies and actions are as follows: to carry out LCA for using straw and other crop residues for energy taking into account the application of fertilizers, which must compensate the loss of nutrients in soil. A number of such LCA was done by UABio but without consideration of fertilizers. Another suggestion is to raise awareness of farmers regarding the value of agricultural residues and the right approach to their potential use for energy. Social media can contribute to bringing relevant information to the farmers.

Who can conduct the studies?

Specialized organizations, institutions, experts, consultants.

4 Conclusions and recommendations

The workshop brought together a group of experts in soil science and bioenergy and relevant stakeholders from the agro and bioenergy sector in Ukraine. The presentations offered a good overview of the current status of knowledge in Europe and the US on the use of crop residues in relation to soil quality.

The issue of removal of crop residues for bioenergy and its potential impact on soil fertility is especially relevant for Ukraine, as the use of crop residues is increasing, whereas soil fertility decline is an import issue. The reasons for the decline are mainly under fertilisation, lack of crop rotations and field burning of crop residues. Although the decline in soil fertility seems to slow down, due to increased fertilization over the last few years, in most soils the decline is still ongoing.

Most of the people at the workshop see potential for using crop residues for bioenergy, however no single recommendation on the amount of crop residues that can be harvested can be given, as this should be based on the local situation, taking soil and crop type, crop yield and management practices into account. In situations with low crop yields and relatively high soil organic matter contents, there will be low potential for crop residue use, but in situations with high crop yields and positive soil organic matter balances, there is much more potential. Using residues for bioenergy is more sustainable compared to field burning, which is still frequently occurring in Ukraine.

Accompanying practices might be required to prevent the possible decline in nutrients and soil organic matter. These measures comprise changes in soil management, such as use of reduced or no tillage, increased use of organic inputs and use of cover crops, measures that are all part of conservation agriculture. Such practices can also have additional benefits for the soil, such as increased infiltration and reduced erosion. Also more technical measures, like the use of hybrid combines that leave more residues on the field, or precision agriculture, can contribute to both increased use of crop residues and maintain soil fertility.

Based on the expert presentations and the discussions at the workshop, the following recommendations are proposed:

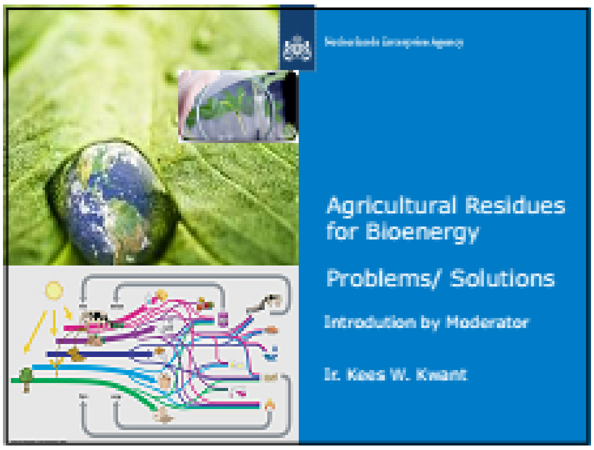
- Crop residue removal rates should be determined region and farm specific, taking account of the crop and soil type and the soil and crop management. A minimum requirement should be the conservation of the current level of soil fertility and humus balance.
- Good spatially explicit data and model implementation is key for making informed decisions on the use of crop residues.
- Potential practices that reduce the risk of decline in soil fertility, such as no tillage, cover crops, hybrid combines and harvesting frequency, have to be further quantified and tested in practice.
- The use of showcase farms can be an effective way to demonstrate the improved practices to other farmers and encourage the uptake of these new practices.
- Setting up an integrated research project that will assess both the biophysical and economic aspects of using crop residues for bioenergy and application of potential practices to maintain soil fertility. Long-term soil organic matter monitoring experiments are required to validate the effectiveness of these strategies. Life Cycle Assessment should be used to evaluate the different strategies, including the cultivation of perennial bioenergy crops on marginal land and competitive uses of crop residues.

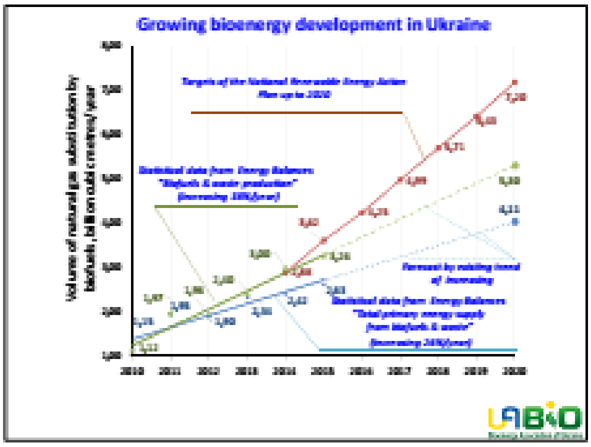
Annex 1 Programme of the workshop

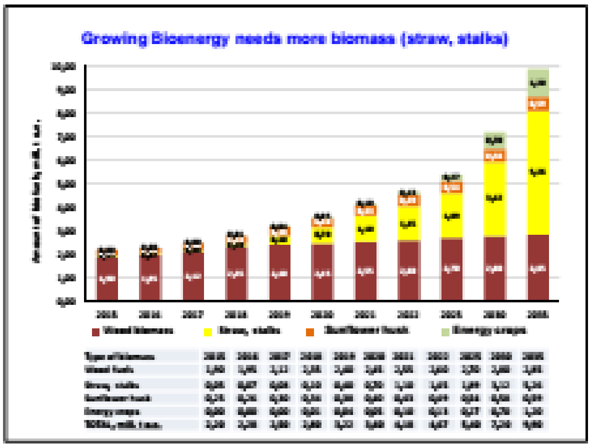
Time	Topic	Speaker
8:30 - 9:00	***Registration and welcome coffee***	
9:00 - 9:15	Opening of the Workshop	• Head of State Agency of Energy Efficiency and Energy Saving of Ukraine, Sergii Savchuk • Agricultural Counselor, Embassy of the Netherlands in Ukraine, Carolien Spaans
9:15 – 9:20	Introduction of moderator	Kees Kwant, Netherlands Enterprise Agency
9:20 – 9:50	The state of fertility of soils in Ukraine	Yuri Kryvda, State Institution "Soils Protection Institute of Ukraine" (Ukraine)
9:50 – 10:20	Research in the USA on sustainable use of crop residues for energy	Dr. Francisco J. Arriaga University of Wisconsin-Madison Soil and Water Management Specialist
10:20 – 10:30	***Break***	
10:30 – 11:00	Experience in the EU with sustainable use of crop residues for energy	Nicolae Scarlat, JRC (Italy)
11:00 – 11:30	Agricultural residues for bioenergy. Problems and solutions	Jan Peter Lesschen, Wageningen UR (The Netherlands)
11:30 – 12:00	Using residues vs using biomass crops for energy	Mykola Royik, Institute of bioenergy crops and sugar beet of NAAS (Ukraine)
12:00 – 13:00	Lunch	
13:00 – 13:30	Recommendation from FAO on using agri-residues – Is Ukraine different?	Sandra Corsi, Food and Agriculture Organization of the United Nations (FAO)
13:30 – 14:00	Options for harvesting straw of higher quality while leaving more nutrients behind	Luigi Pari, CREA (Italy)
14:00 – 14:30	REACTIONS from panel	• Policy: Ukraine Ministry of agriculture: Policy view • Industry: Agro Holdings • Financial institutions • Bioenergy association of Ukraine
14:30 – 15:00	***Break***	
15:00 – 16:00	Collaborative formulation of recommendations and research questions	4 to 6 groups
16:00 – 16:30	Reporting per group	Reporting by Tetiana Zheliezna (UABio) and Jan Peter Lesschen (WUR)
16:30 – 17:00	Formulation of conclusions	Wolter Elbersen, Wageningen UR (The Netherlands)
17:00	***Closure of Workshop and Drinks***	

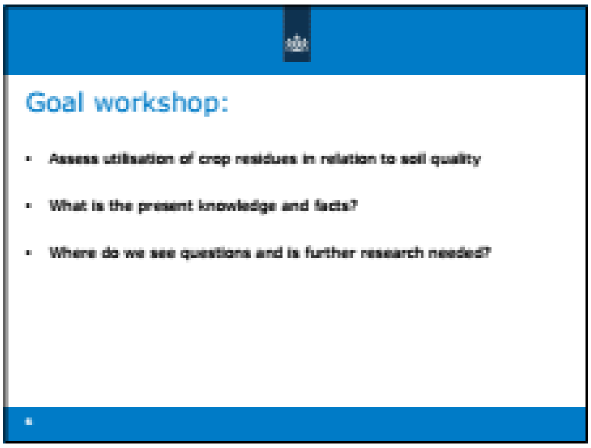
Annex 2 Slides of the expert presentations

Kees Kwant, Netherlands Enterprise Agency: Introduction of moderator

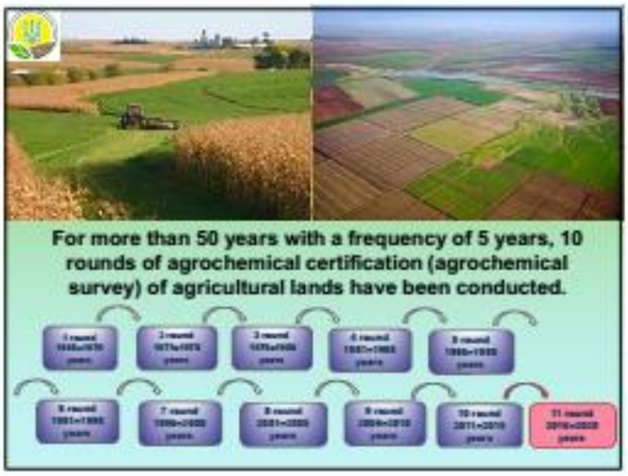


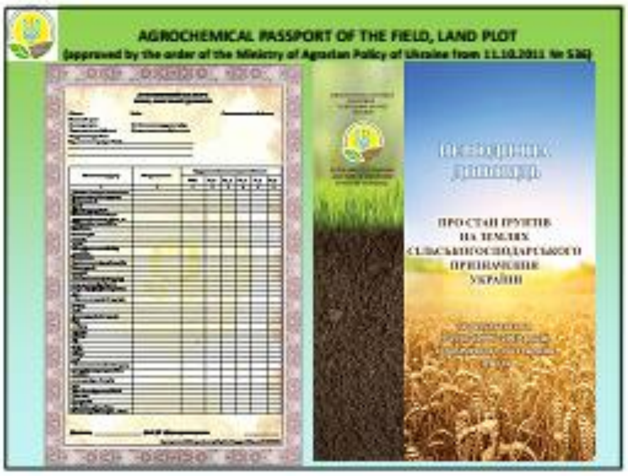






Yuri Kryvda (Soils Protection Institute of Ukraine): The state of fertility of soils in Ukraine





- **Soil** is a natural-historical organo-mineral body formed on the surface of the earth's crust and is the center of the greatest concentration of nutrients, the basis of life and development of mankind due to its most valuable property - fertility.
- **Soil fertility** - the ability of the soil to meet the needs of plants in nutrients, water, air and heat in sufficient quantities for their normal development, which together is the main indicator of soil quality.

The Law of Ukraine "On Land Protection"

7

Indicators of soil investigation

General:
1. The thickness of the humus profile of the soil
2. Depth of arable layer of soil
3. Physical clay

Agrophysical:
1. Bulk density
2. Bulk weight
3. Aggregate state
4. Least moisture capacity

Agrochemical:
1. Humus
2. NO_3^-
3. NH_4^+
4. P_2O_5 (mobile)
5. K_2O (exchangeable)

Physico-chemical:
1. Hydrolytic acidity
2. pH of the salt extract
3. Сума ввібраних основ (Ca+Mg)
4. Exchangeable Ca^{2+} and Mg^{2+}
5. Exchangeable Na^+
6. Total Nitrogen
7. P_2O_5 (gross)
8. K_2O (gross)
9. CO_2 of carbonates

Contaminants:
1. Specific activity of Bq./m², Cs^{137} Bq. kg^{-1}, Sr^{90} Bq. kg^{-1}
2. Pb, Cd, Cu, Zn (1M HCl), Hg
3. remnants of resistant and highly toxic pesticides used in a calendar year

Mobile forms of chemical elements acetate ammonium buffer extract 4,5:

1. Zn 2. Cu
3. Mn 4. Co
5. Bo 6. Mo
7. Pb 8. Cd
9. Fe 10. Cr

8

Soil degradation

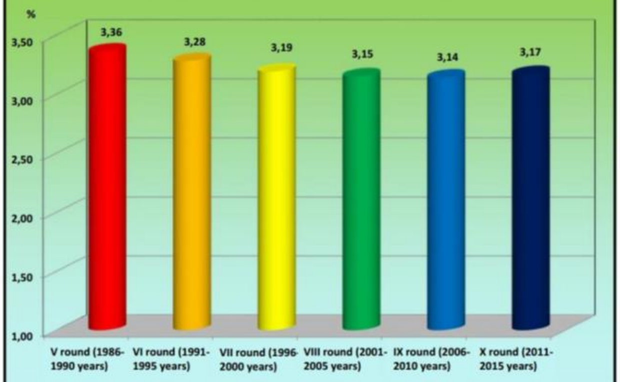
Soil degradation - deterioration of useful properties and soil fertility due to natural or man-made factors.

The main types of soil degradation are:
- **physical degradation (compaction, disaggregation, cohesion, etc.);**
- **erosion (wash off, wash out) and deflation;**
- **waterlogging, underflooding, flooding;**
- ***depletion (dehumification, acidification, alkalization, trophic depletion, secondary salinization, alkalinization);***
- ***contamination with heavy metals, pesticides, petroleum products, other organic and biological pollutants, radionuclides.***

Soil fertility - the ability of the soil to meet the needs of plants in nutrients, water, air and heat in sufficient quantities for their normal development, which together is the main indicator of soil quality.

9

Dynamics of organic matter content in soils of Ukraine

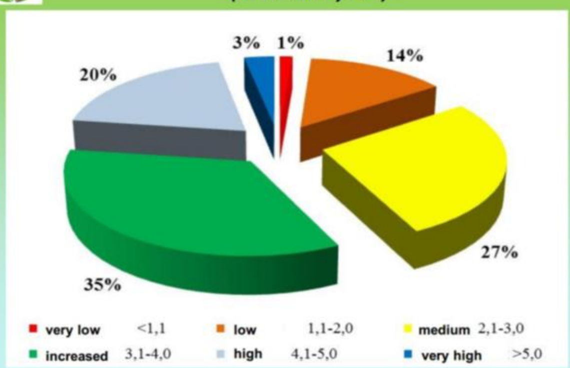


10

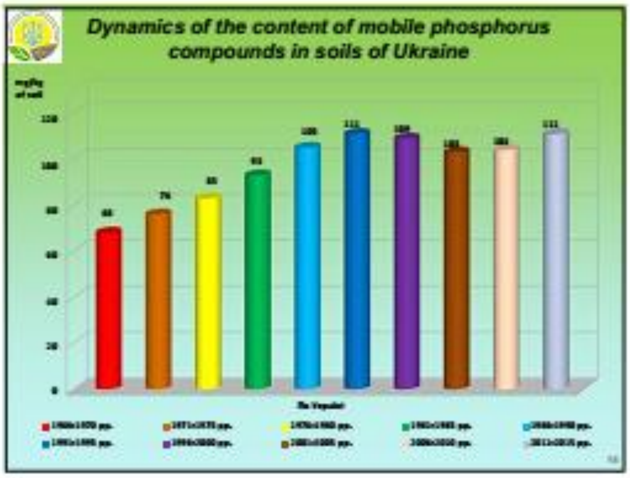
Dynamics of humus content in the soils of Cherkasy oblast

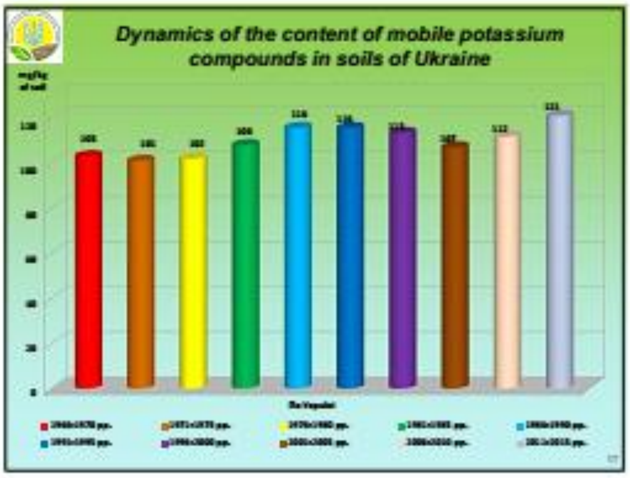
№ region	Name of the region	Humus content, %		
		1981-1985 years	1991-1995 years	2011-2016 years
2	Drabivskyi	4.36	3.76	3.89
19	Chornobayivskyi	3.65	3.60	3.64
3	Zhashkivskyi	3.78	3.90	3.54
20	Shpolyanskyi	3.64	3.22	3.45
14	Tal`nivs`kyi	3.52	3.38	3.38
8	Katerynopil`s`kyi	3.61	3.42	3.37
16	Khrystynivs`kyi	3.41	3.26	3.34
15	Umans`kyi	3.37	3.40	3.29
12	Monastyryshchens`kyi	3.37	3.24	3.19
11	Man`kivs`kyi	3.11	3.00	3.13
9	K-Shevchenkibs`kyi	2.38	2.65	3.10
6	Kamyans`kyi	3.04	3.02	2.98
5	Zolotonis`kyi	3.28	3.50	2.97
13	Smilyans`kyi	2.92	2.70	2.90
1	Horodyshchens`kyi	3.06	2.96	2.95
10	Lysyans`kyi	3.38	3.08	2.93
4	Zvenyhorods`kyi	2.8	3.00	2.80
7	Kanivs`kyi	2.29	2.82	2.53
18	Chyhyryns`kyi	2.49	2.80	2.27
17	Cherkas`kyi	2.35	2.52	2.26
	Average in OBLAST	**3.27**	**3.25**	**3.05**

Grouping of soils of Ukraine according to humus content (2011–2015 years)



12



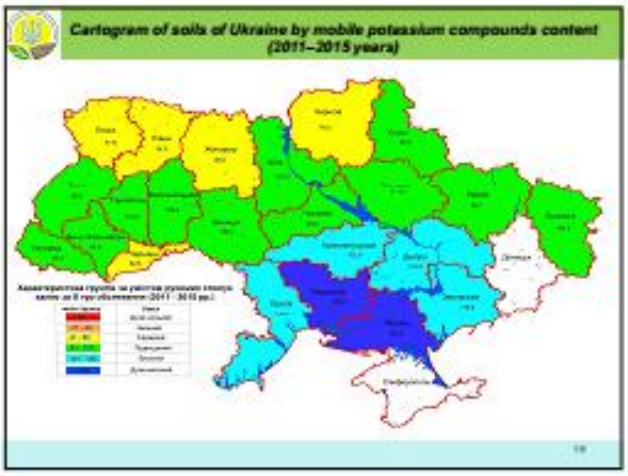


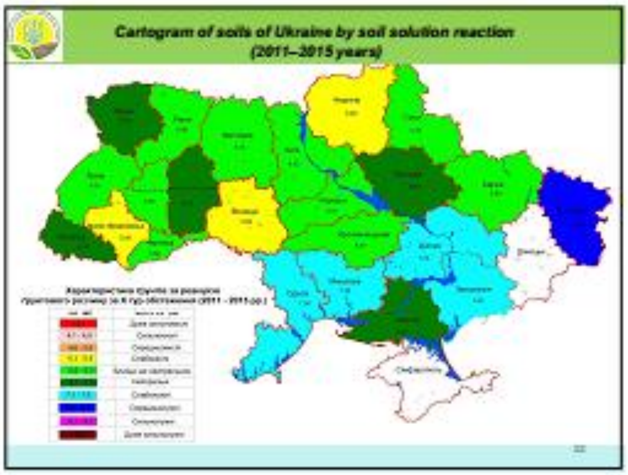
Dynamics of the content of mobile phosphates in the soils of Cherkasy oblast

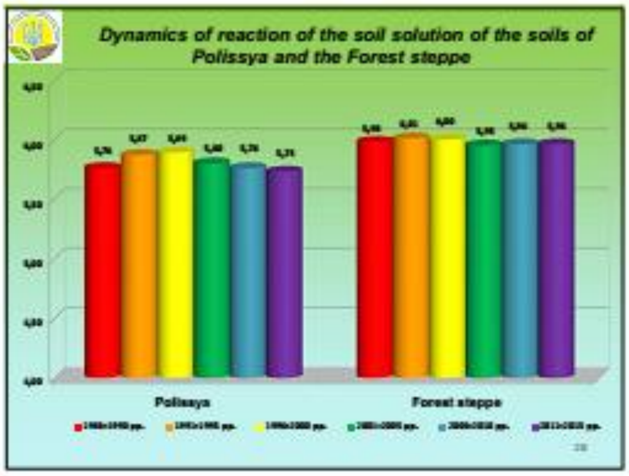
№ region	Name of the region	Phosphorus content, mg/kg		
		1971-1975 years	1991- 1995 years	2011-2016 years
7	Kanivs'kyi	123	146	172
17	Cherkas'kyi	95	170	172
12	Monastyryshchens'kyi	115	148	156
13	Smilyans'kyi	102	151	145
3	Zhashkivskyi	117	164	148
9	K-Shevchenkivs'kyi	112	143	148
20	Shpolyanskyi	93	138	145
11	Man'kivs'kyi	98	142	140
4	Zvenyhorods'kyi	88	135	137
6	Kamyans'kyi	104	138	134
16	Khrystynivs'kyi	112	138	130
5	Zolotonis'kyi	103	174	127
10	Lysyans'kyi	98	131	126
2	Drabivskyi	118	154	123
1	Horodyshchens'kyi	117	151	121
15	Umans'kyi	84	111	121
14	Tal'nivs'kyi	87	130	110
8	Katerynopil's'kyi	80	128	107
19	Chornobayivskyi	146	159	102
18	Chyhyryns'kyi	91	138	98
	Average in OBLAST	102	142	130

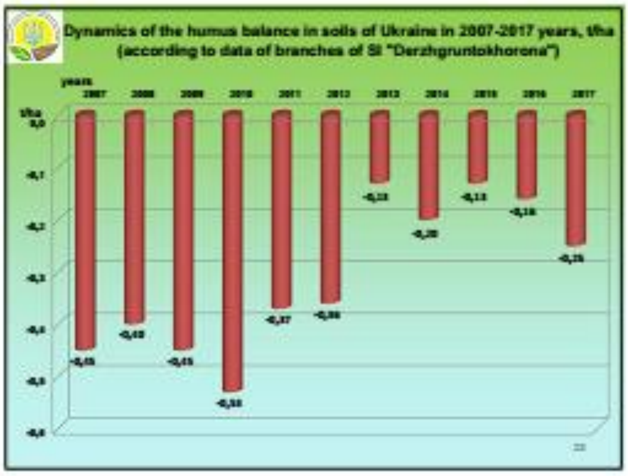
Dynamics of the content of mobile potassium in the soils of Cherkasy oblast

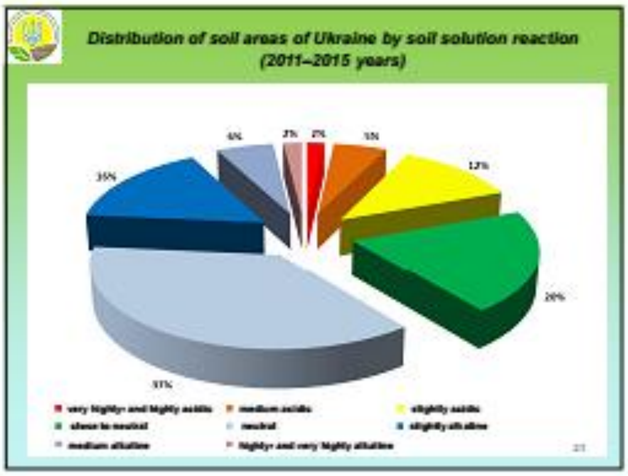
№ region	Name of the region	Potassium content, mg/kg		
		1971-1975 years	1995-2000 years	2011-2016 years
11	Man'kivs'kyi	87	123	142
20	Shpolyanskyi	84	115	121
6	Kamyans'kyi	73	110	116
3	Zhashkivskyi	76	108	112
15	Umans'kyi	99	122	110
16	Khrystynivs'kyi	95	113	107
13	Smilyans'kyi	69	112	103
14	Tal'nivs'kyi	92	121	99
2	Drabivskyi	63	96	97
8	Katerynopil's'kyi	86	108	93
1	Horodyshchens'kyi	64	104	92
12	Monastyryshchens'kyi	85	119	91
4	Zvenyhorods'kyi	89	122	90
10	Lysyans'kyi	87	107	88
9	K-Shevchenkivs'kyi	59	108	81
7	Kanivs'kyi	54	100	80
17	Cherkas'kyi	44	91	80
5	Zolotonis'kyi	52	95	68
18	Chyhyryns'kyi	52	94	66
19	Chornobayivskyi	59	124	66
	Average in OBLAST	74	106	91

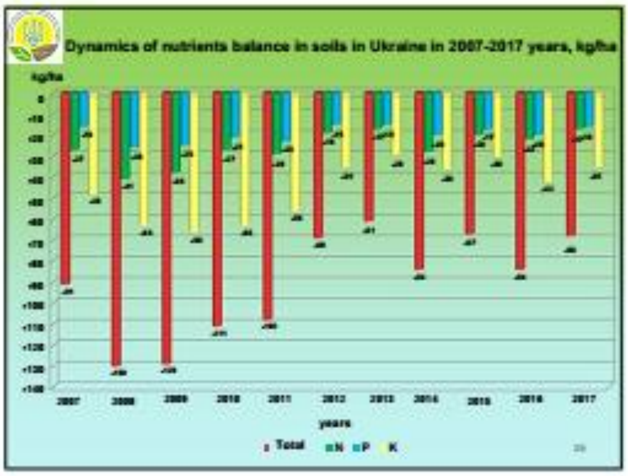

Cartogram of soils of Ukraine by mobile potassium compounds content
(2011–2015 years)


Cartogram of soils of Ukraine by soil solution reaction
(2011–2015 years)


Dynamics of reaction of the soil solution of the soils of Polissya and the Forest steppe
Polissya
Forest steppe

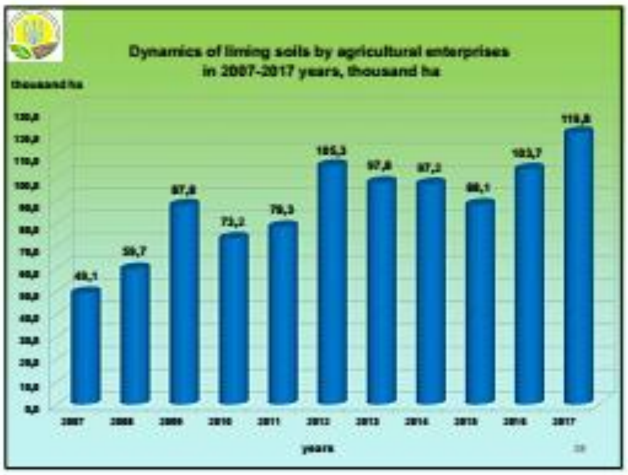

Dynamics of the humus balance in soils of Ukraine in 2007-2017 years, t/ha
(according to data of branches of SI "Derzhgruntokhorona")
years
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
t/ha
-0,45
-0,40
-0,45
-0,53
-0,37
-0,36
-0,13
-0,20
-0,13
-0,16
-0,25

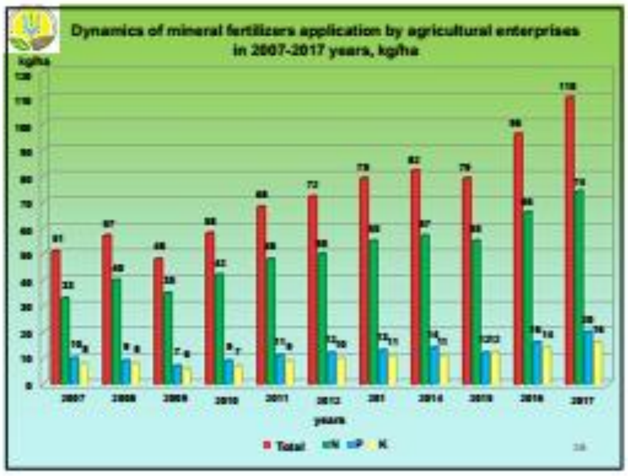

Distribution of soil areas of Ukraine by soil solution reaction
(2011–2015 years)
very highly- and highly acidic
medium acidic
slightly acidic
close to neutral
neutral
slightly alkaline
medium alkaline
highly- and very highly alkaline


Dynamics of nutrients balance in soils in Ukraine in 2007-2017 years, kg/ha
kg/ha
years
Total
N
P
K

Dynamics of nutrients balance in the crop farming of Cherkasy oblast, kg/ha

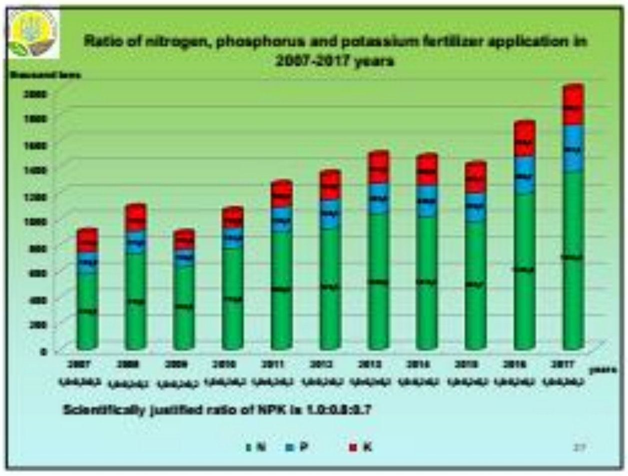
Balance lines	Nitrogen	Phosphorus	Potassium	Total
1	2	3	4	5
1986–1990				
Addition	157.8	71.8	125.0	354.3
Removal	100.7	39.3	71.0	210.7
Balance, ±	57.1	32.5	54.0	143.6
2014				
Addition	86.7	20.2	29.8	134.9
Removal	106.4	34.4	34.7	175.5
Balance, ±	-19.7	-14.2	-6.7	-40.6
2015				
Addition	86.4	18.6	28.5	131.5
Removal	109.3	34.2	37.1	180.7
Balance, ±	-22.9	-15.6	-8.6	-47.2
2016				
Addition	87	20	24	131
Removal	148	52	163	363
Balance, ±	-61	-32	-139	-232

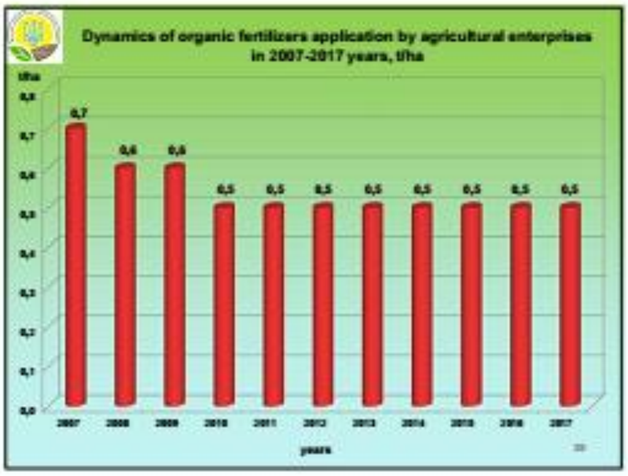




Liming of acidic soils in Cherkasy oblast (1986 – 2016 years)

Name of the region	1986-1990 (average)	1991-1995 (average)	1996-2000 (average)	2001-2005 (average)	2006-2010 (average)	2011-2015 (average)	2015	2016
	thousand ha	thousand ha	thousand ha	thousand ha	thousand ha	thousand ha	thousand ha	thousand ha
Horodyshchens'kyi		3.0	0.620	0.24	0.10	0,91		0,2
Drabivs'kyi	2.8	1.5	0.429		0.07	0,49		0,9
Zhashkivs'kyi	4.7	3.1	0.216	0.07	0.33	0,006	0,03	
Zvenyhorods'kyi	6.9	4.1	0.471	0.25	1.21	0,57	0,54	1,1
Zolotonis'kyi	7.2	3.2	0.326	0.63	0.42	0,78	0,28	2,7
Kamyans'kyi	9.1	2.9	0.303	0.04		0,15		
Kanivs'kyi	9.2	3.2	0.311	0.01		0,4	0,60	
Katerynopil's'kyi	5.4	4.8	0.360	0.04		0,18		0,3
Korsun-Shevchenkivs'kyi	4.9	3.8	0.397	0.26	1.07	1,2	0,78	1,9
Lysyans'kyi	3.4	3.4	0.208	0.02	0.34	0,12		0,2
Man'kivs'kyi	5.8	4.1	0.492	1.00	0.96	0,77	0,44	0,3
Monastyryshchens'kyi	5.4	4.1	0.413		0.62	0,1		
Smilyans'kyi	5.7	4.1	0.159	0.09	0.08	0,02		
Tal'nivs'kyi	6.3	5.6	1.300	0.15		0,48		
Umans'kyi	11.8	7.1	0.650	0.03	0.63	0,002		
Khrystynivs'kyi	7.0	5.9	0.354	0.50	0.12	0,8	0,78	0,8
Cherkas'kyi	5.6	2.9	0.108	0.06	0.28	0,9	0,51	0,3
Chyhyryns'kyi	5.4	2.2	0.279			0,1		
Chornobayivs'kyi	5.6	2.9	0.108	0.19	0.04	0,02		
Shpolyans'kyi	14.6	23.9	3.999	0.06	0.01	0,12		
Total for oblast	117.2	94.3	11.48	3.67	7.01	8,05	3,89	8,4





Dynamics of plowing green manure in 2007-2017 years, thousand ha
(according to data of branches of SI "Derzhgruntokhorona")

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Removal of the main nutrients by maize for grain, kg/ha

Crop yield, centners / ha		main product			by-product			main product + by-product		
		N	*P*	*K*	*N*	*P*	*K*	*N*	*P*	*K*
	1.0	1.37	0.53	0.38	0.64	0.19	1.40	2.40	0.90	2.60
	50.0	68.50	26.50	19.00	32.00	9.50	70.00	120.00	45.00	130.00
2016	77.7	106.45	41.18	29.53 177	49.73	14.76	108.78	186.48	69.93	202.02 458
	105.0	144.40	55.86	40.05 240	67.46	20.03	147.56	252.96	94.86	274.04 622

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Dynamics of straw application in 2007-2017 years, thousand ha
(according to data of branches of SI "Derzhgruntokhorona")

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Cost of non-commodity part of crop yield,

(without logistics – collection, baling, transportation of straw (corn, sunflower), fertilizing, planting green manure crops)

Products	Humification coefficient of plant residues	Content in 1 t/kg			The cost of alienation of 1 ton of non-commodity part of the harvest, UAH				
		N	P	K	Humus	N	P	K	Total
Straw of winter wheat	0,25	4,5	1,4	9,3	826	130	55	167	1178
Haulms of corn for grain	0,15	6,4	1,9	14,0	496	185	74	252	1007
Haulms of sunflower	0,15	7,9	2,7	43,3	495	229	105	779	1608

Cost:
- 1 ton of humus – 114 USD (1 USD – 29 UAH);
- 1 kg of Nitrogen – 29 UAH (Ammonium nitrate – 9860 UAH/t);
- 1 kg of Phosphorus 39 UAH (Simple superphosphate – 7800 UAH/t);
- 1 kg Potassium 18 UAH (Potassium chloride – 10880 UAH/t)

35

Removal of the main nutrients by winter wheat, kg / ha

Crop yield, centners / ha		main product			by-product			main product + by-product		
		N	*P*	*K*	*N*	*P*	*K*	*N*	*P*	*K*
	1.0	1.86	0.70	0.44	0.45	0.14	0.93	3.00	1.00	2.40
2016	54.1	100.63	37.87	23.80 162	24.35	7.57	50.31	162.3	54.1	129.84 346

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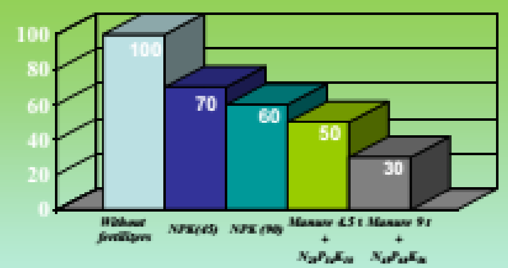

The minimum amount of non-commodity part of crop yield that must be left on the field to conserve humus resources, %

KEY TASKS FOR CONSERVATION AND REPRODUCTION OF SOIL FERTILITY

- optimize the structure of land and, especially, agricultural lands in order to increase the sustainability of agricultural landscapes;
- suspension of humus content decline and achievement of its deficit-free balance;
- soil enrichment with nutrients;
- protection of soils from erosion;
- reclamation of acid soils;
- reconstruction of irrigation systems;
- streamlining of available information on soil fertility;
- working out of the economic mechanism of financing activities for the conservation and restoration of soil fertility

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Thank you for attention!

Dokuchaieva str., 15, Kholodnianske village,
Smilianskiy region, Cherkaska oblast, 20731;
Tel. +380503137748, +380687007450,
E-mail: krivda61@ukr.net

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Francisco J. Arriaga (University of Wisconsin-Madison, USA): Research in the USA on sustainable use of crop residues for energy

Sustainable Use of Crop Residues for Bioenergy: USA Research

Francisco J. Arriaga, PhD
Sustainable Soil Management Lab
Dept. of Soil Science
University of Wisconsin-Madison

Agricultural Residues for Bioenergy: Problems and Solutions Workshop

Outline

- Background on harvest of crop biomass for bioenergy in US
  - What was the impetus in US?
  - Problems that research addressed
- Discussion on research conducted US
  - Impacts on crop yields
  - Impacts on soil organic C and fertility
  - Management options suggested
- Recommendations for plant biomass harvest for bioenergy from a soil sustainability perspective

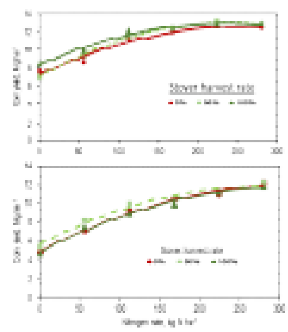
Background

- In the US the main interest on the use of crop residues for energy production has been for liquid fuels to replace petroleum dependence.
  - US already produces ethanol from maize grain. This ethanol is used as an additive in gasoline.
- Crop biomass ethanol was supposed to increase ethanol production to increase percentage used in gasoline.
  - Some work was done for biogas production and direct burning (100% plant biomass or co-fired with coal) for electricity production using plant biomass.
- Maize residue (stover) presents a potential raw material for ethanol production in the US given the large amount of maize grown.
  - Other permanent crops were explored, such as switchgrass (*Panicum virgatum*) and Miscanthus (*Miscanthus x giganteus*, sterile hybrid).
- This presentation will focus on maize residue harvest impacts to soil productivity.

Background - continued

- Concerns for using farm crop residues are related to a decline in crop productivity and soil health.
- Harvesting crop biomass results in a reduction of organic carbon inputs to soil and decreased soil organic matter.
  - Soil organic matter affects soil physical properties, such as water infiltration capacity and plant water availability.
- Crop nutrients in plant biomass are removed from the field during harvest. This results in decreased crop nutrient levels (N, P, K and others) in the soil compared to harvesting just crop grain.
- Data for specific soils, crops, and soil management in a region are key for making biomass harvest' decisions.

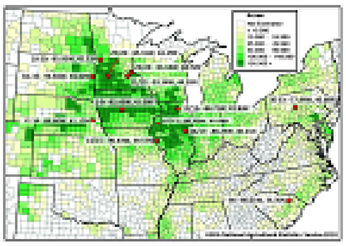
Impact of stover harvest on maize grain yield – Wisconsin 2010-2015



Location: Arlington
Soil: Mollisol

Location: Lancaster
Soil: Alfisol

Comprehensive Maize Residue Harvest Assessment in the Midwest Region of US



- 36 sites, multiple years (239 site-years of data)
- Each site had at least 5 year history
- Treatments:
  1. stover harvest rate
  2. tillage

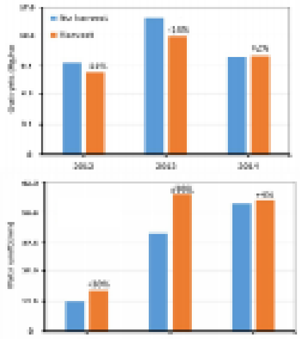
Maize Residue Harvest Assessment – Yield & Soil Fertility Impacts

		Maize Residue Harvest Level		
	County Yield	No harvest	Moderate	High
	——— Grain Yield Mg/ha ———			
Mean	10.2	9.8	10.1	10.1
Range	2.9 – 13.4	1.3 – 16.5	0.6 – 16.7	0.8 – 16.4

Tillage Type	Stover Yield	N Removal	P Removal	K Removal
	–Mg/ha–	——— kg/ha ———		
	Moderate Harvest Level			
Conventional	6.1	24.0	2.6	31.9
No tillage	5.7	24.5	2.8	30.9
LSD(0.05)	ns	ns	ns	ns
	High Harvest Level			
Conventional	7.1	43.3	4.6	59.0
No tillage	7.3	45.7	6.0	61.8
LSD(0.05)	ns	ns	ns	ns

(Source: Sulc et al., 2016)

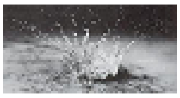
Maize Residue Harvest Increased Water Runoff and Lowered Yield



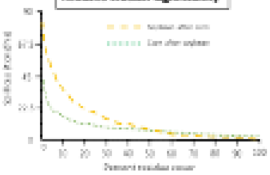
Soil: Eroded Mollisol
Slope: ~ 7%

(Source: Arriaga et al., unpublished data)

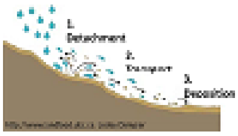
Less Crop Residues on Soil Surface Increase the Risk for Erosion

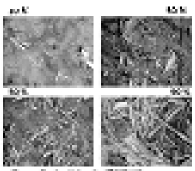


30% Residue on Soil Surface Reduces Erosion Significantly



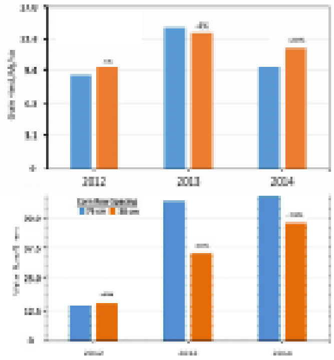
Water Erosion Process





(Source: Purdue University AY-Web)

Narrow Maize Row Spacing Reduced Water Runoff with Minor Impact to Grain Yield



Soil: Eroded Mollisol
Slope: ~ 7%

(Source: Arriaga et al., unpublished data)

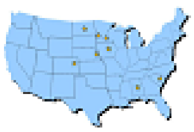
Less Crop Residues, Concern for Erosion – Management Practices can Help

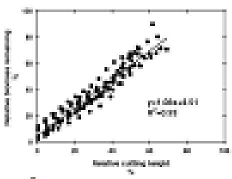
				Maize - Maize		Maize - Soybean	
State	Soil	Slope	T †	Conventional	Conservation	Conventional	Conservation
		-- % --		——— Mg/ha ———			
Iowa	silty clay loam	0 – 2	11.2	3.6	0.9	11.8	1.0
Illinois	silt loam	2 – 4	9.0	9.8	1.4	11.8	1.8
Indiana	loam complex	1 – 4	9.0	7.5	1.2	11.8	1.6
Michigan	loam	0 – 6	9.0	3.2	0.8	3.2	0.8
Minnesota	silt loam	2 – 6	11.2	0.1	0.1	2.5	0.1
Minnesota	loam	2 – 6	11.2	0.1	0.1	3.4	0.1
Nebraska	silt loam	3 – 5	11.2	3.7	0.1	11.8	1.0
Ohio	loam	0 – 2	9.0	2.1	1.1	11.8	1.4
South Dakota	silty clay loam	2 – 6	11.2	0.1	0.1	0.1	0.1
Wisconsin	silt loam	2 – 6	9.0	1.6	0.8	11.8	1.4
Mean				3.1	0.7	4.6	1.6
Standard Error				1.0	0.2	1.4	0.2

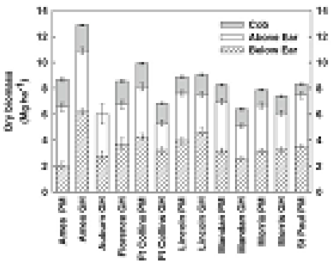
† : T is the tolerable soil loss. This value varies depending on depth of A soil horizon.

(Source: Wilhelm et al., 2007)

Knowing the Relationship of Harvestable Biomass and Plant Portion for Specific Crops can be Useful…



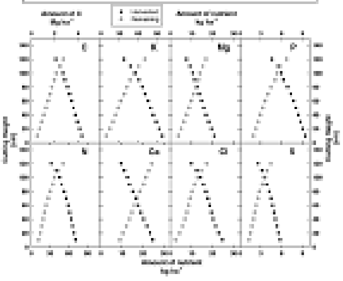




(Source: Wilhelm et al., 2011)

…and can Help in Making Management Decisions at the Field Scale

Relationship of Cutting Height and Chemical Element Amount for Maize



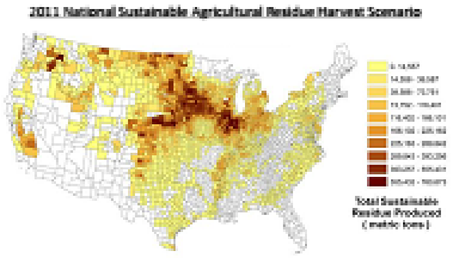
(Source: Johnson et al., 2010)

Overall Recommendations

- Crop biomass harvest can be done with minor impacts to soil and environment when done properly.
  - Consider harvesting only a portion of the biomass and/or use cover crops to protect soil from erosion and provide organic carbon for soil health.
  - Crop nutrients will have to be replaced with commercial fertilizers or manures.
  - There might be a greater risk for soil compaction due to the additional equipment traffic.
  - Runoff and erosion can be a problem in sloping soils, even with reduced tillage practices. Permanent bioenergy crops can be used in these areas.
- Data and model implementation for making informed decisions is key.

Inventories that Take into Account Soil and Crop Regional Factors

2011 National Sustainable Agricultural Residue Harvest Scenario



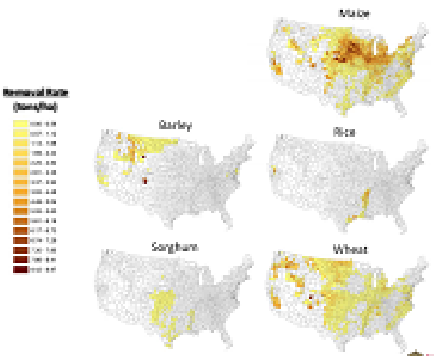
Source: (Muth et al., 2013)

References

- Johnson, J.M.F., W.W. Wilhelm, D.L. Karlen, [illegible] 2010. [illegible] BioEnergy Research [illegible]
- Karlen, D.L., [illegible] BioEnergy Research [illegible]
- Wilhelm, W.W., J.M.F. Johnson, [illegible] 2011. [illegible] BioEnergy Research [illegible]
- Wilhelm, W.W., J.M.F. Johnson, D.L. Karlen, and D.T. Lightle. 2007. [illegible] Agronomy Journal [illegible]
- Muth Jr., D.J., K.M. Bryden, and R.G. Nelson. 2013. [illegible] Applied Energy [illegible]

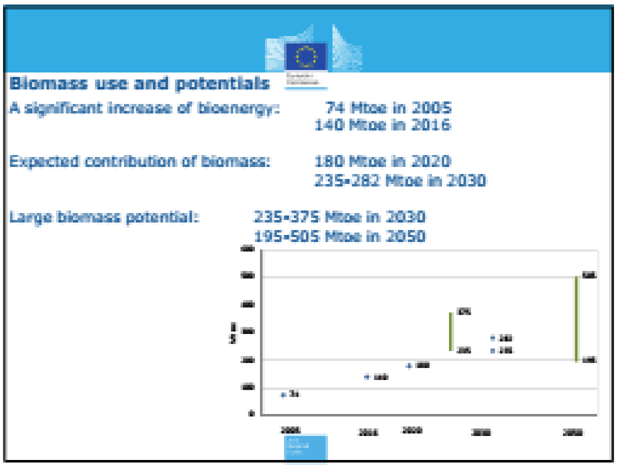
Maize Harvested for Silage

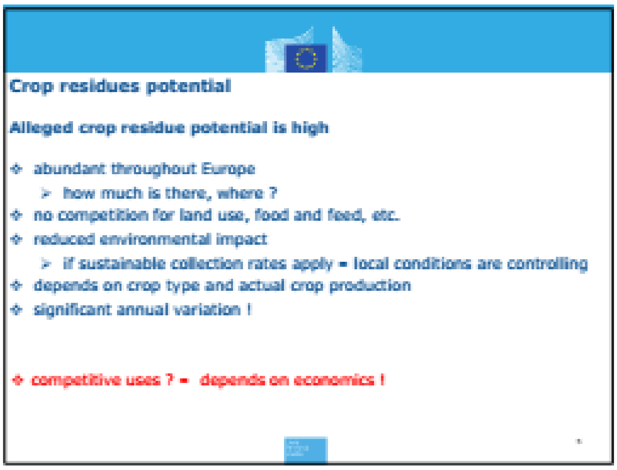
Sustainable Harvested Rate by Crop

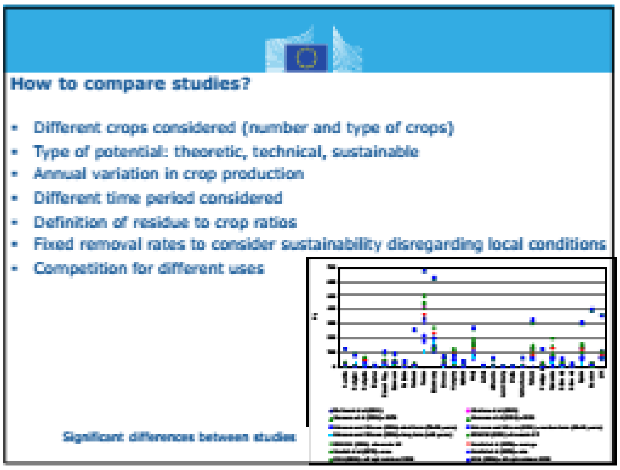


Source: (Muth et al., 2013)

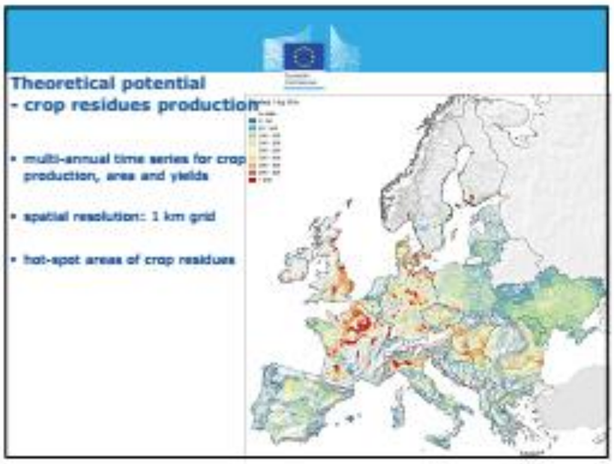
Nicolae Scarlat (JRC, Italy): Experience in the EU with sustainable use of crop residues for energy

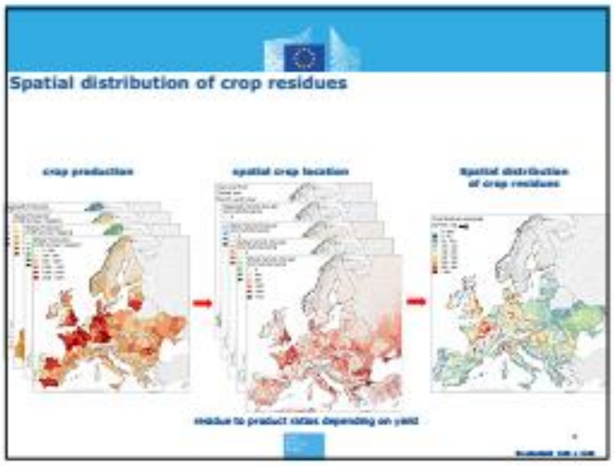


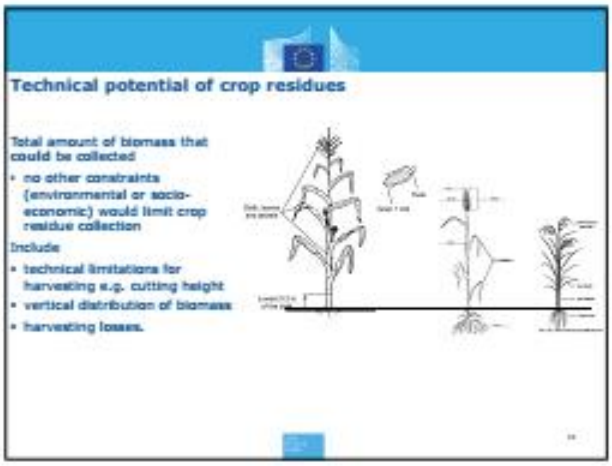


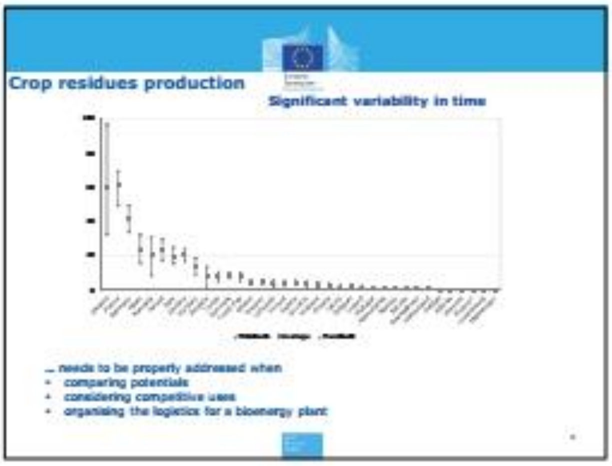


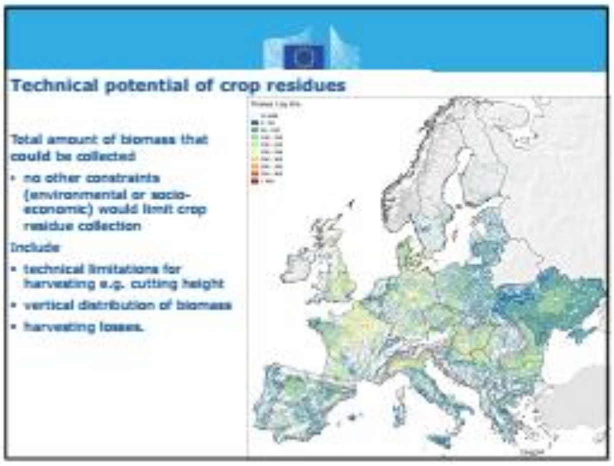

Crop residues potentials
Crop production
• main crops: wheat, barley, oat, rye, maize, rapeseed, rice and sunflower
• multi-annual time series for crop production on enlarged geographical scope
• spatial distribution of crops: 1 km spatial resolution
Crop residues theoretical potential (residues production)
• residue to grain ratios, depending on yield
• multi-annual averages
Technical potential
• limitations for biomass collection due to the equipment,
• technical losses at collection
Environmental potential
• agro-ecosystem model
• sustainable removal rates
Sustainable potential
• actual collectable residues
• considers both technical and environmental constraints for mobilisation


Theoretical potential
- crop residues production
• multi-annual time series for crop production, area and yields
• spatial resolution: 1 km grid
• hot-spot areas of crop residues


Spatial distribution of crop residues
crop production
spatial crop location
Spatial distribution of crop residues
residue to product ratios depending on yield


Technical potential of crop residues
Total amount of biomass that could be collected
• no other constraints (environmental or socio-economic) would limit crop residue collection
Include
• technical limitations for harvesting e.g. cutting height
• vertical distribution of biomass
• harvesting losses.


Crop residues production
Significant variability in time
… needs to be properly addressed when
• comparing potentials
• considering competitive uses
• organising the logistics for a bioenergy plant


Technical potential of crop residues
Total amount of biomass that could be collected
• no other constraints (environmental or socio-economic) would limit crop residue collection
Include
• technical limitations for harvesting e.g. cutting height
• vertical distribution of biomass
• harvesting losses.

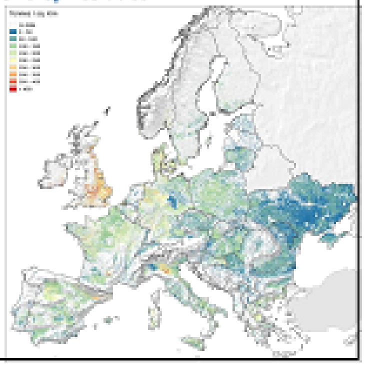
Sustainability of crop residues collection

The effect of residue removal rates on SOC stock change

- Agro-ecosystem Century Model
- Soil data - European Soil Database - ESDB
- Climate
  - European Climate Assessment & Dataset project
  - Global Climate Change Models (IPCC)
- Agricultural land - Corine Land Cover, Land Cover CCI
- Crop rotation - Eurostat, national statistics
- Three scenarios for biomass removal
  - 50% crop residues removal
  - no residues removal
  - total crop residues removal

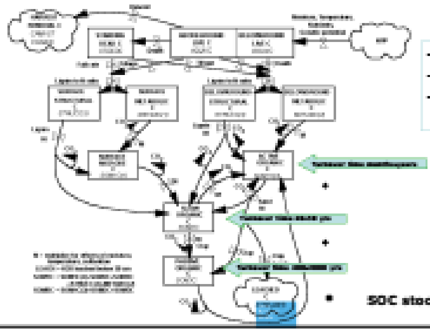
Environmental potential of crop residues

The effect of residue removal rates on SOC stock change due to biomass removal



Mechanistic SOC models

CENTURY model vers. 4 (Process-based, multi-compartment)



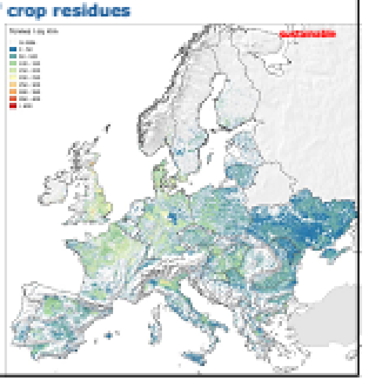
- Widely used
- Monthly time-step
- Simulating arable, permanent crops

SOC stock

Sustainable potential of crop residues

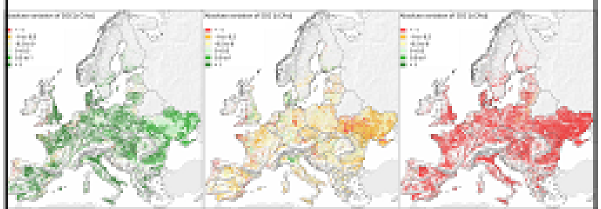
- considers both technical and environmental constraints for biomass mobilisation (min. values for each location (pixel)
- actual collectable residues

total potential for all uses



Sustainability of crop residues collection

Absolute variation of SOC in the mid-term (2015 to 2030)



1- no residues collection

2) 50% residues collection

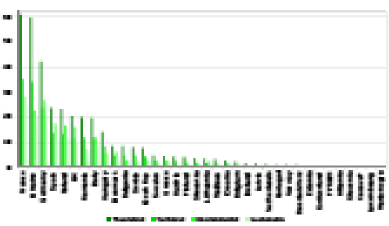
3) full residues collection

Crop residues potentials

From

- Theoretical potential (production) to
- Technical potential
- Environmental potential
- Sustainable potential

	Theoretical	Technical	Environmental	Sustainable
EU	291	168	162	124
Europe	368	212	190	149

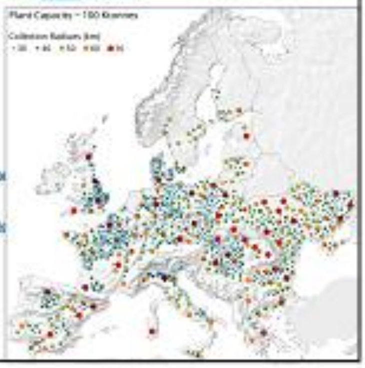


Plant locations

Map of potential plants

- Find most favourable site
- Establish plant capacity within a certain area
- Establish collection radius for a certain capacity

Optimal plant capacity depends on available resources and collection costs



Conclusions

- Harmonized methodology at the level of EU
- Based on validated model, soil and climate data
- Sustainability of residues removal in terms of SOC preservation
- Continental data bases provide wide views - local assessment has to be complemented with local data

Open issues:

- Soil Organic Carbon is not the only sustainability indicator!
- Preserving SOC = is it enough? or should we need to increase it?
- Spatial explicit assessment is essential for accurate resource evaluation, considering local conditions

Recommendations for the use of crop residues

- sustainable removal: local conditions are critical
- the use of different cultivars
- consider competitive uses
- dealing with annual variability
- compensatory measures for soil fertility

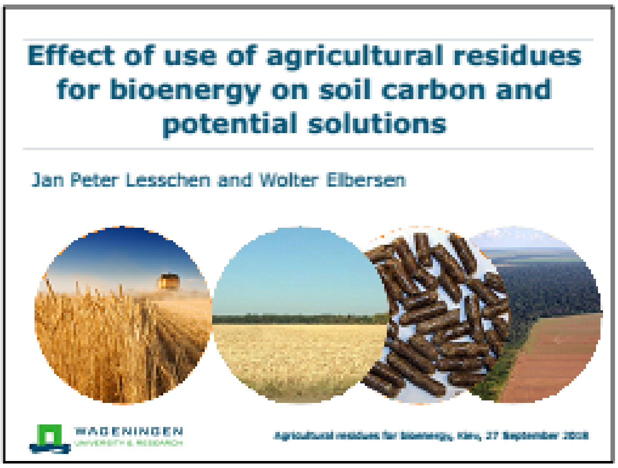
Open issues

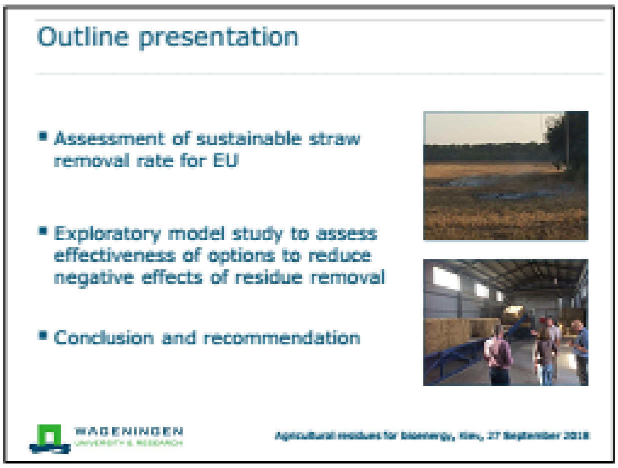
- farmers decision
- logistics and costs
- raising awareness

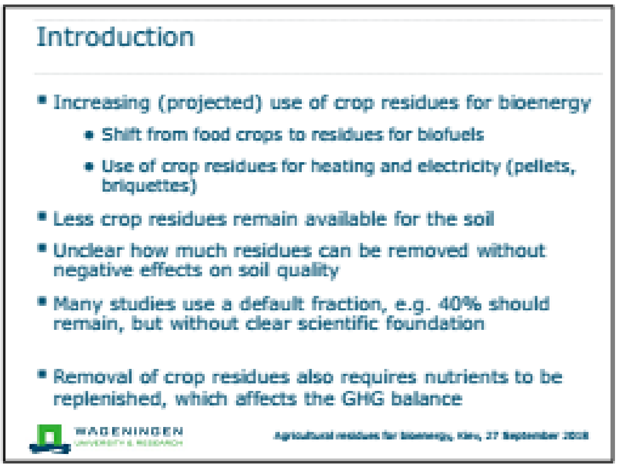
Research priorities

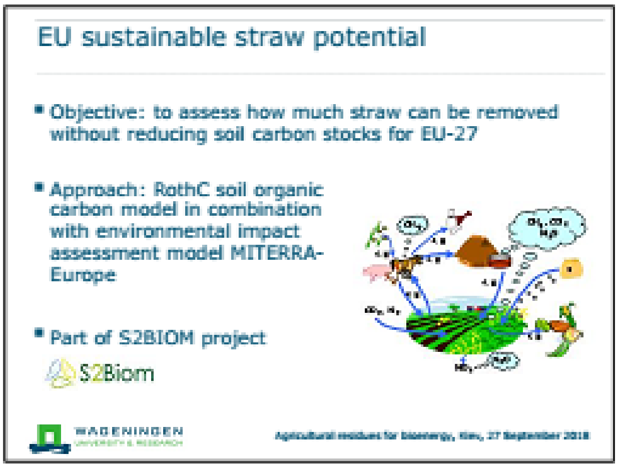
- spatial distribution of crops, crop rotation
- modelling soil organic matter
- local crop yields yield
- competitive uses
- technology, the use of straw pellets/briquettes
- economics

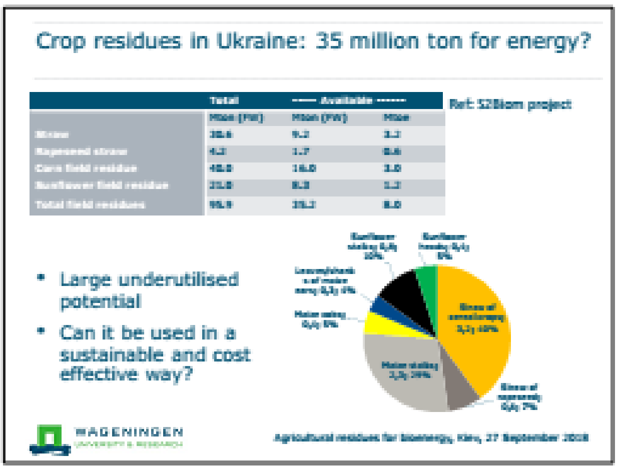
Jan Peter Lesschen (Wageningen University and Research, The Netherlands: Agricultural residues for bioenergy. Problems and solutions

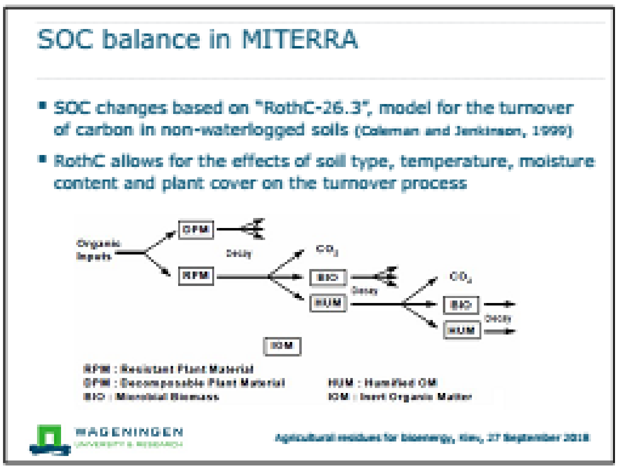








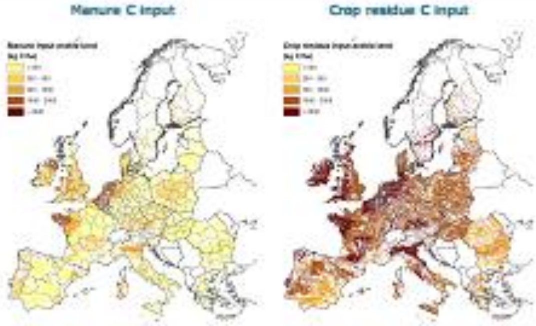




SOC balance in MITERRA-Europe

- SOC stock based on LUCAS data (0-20 cm)
  - Soil sampled at 22000 locations in 2009
  - Bulk density with pedo-transfer function
  - Peat soils (>12% SOC) excluded
- Climate data
  - Monthly temperature, precipitation and potential evapotranspiration (WorldClim and FAO)
- Carbon inputs
  - Manure (based on N flows and CN-ratio)
  - Crop residues (regional yield data, harvest index (Vleeshouwers and Verhagen, 2002), residue removal rate)

Carbon inputs arable land



C input straw crops

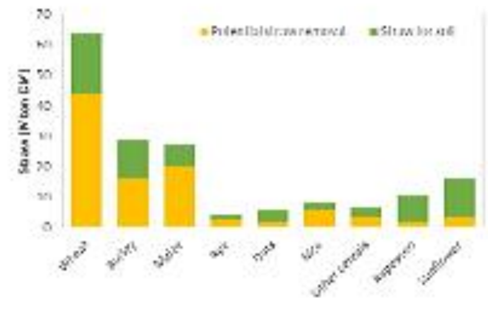
- Same approach as for SOC balance, but detailed data of C input
- Wheat, barley, rye, oats, rice, other cereals, rapeseed and sunflower
- C quantified for four components:
  - Grain yield at regional level (Eurostat)
  - Above ground residues (according to Scarlat et al., 2010) using yield dependent formula
  - Straw : Stubble/chaff = 55:45 ratio
  - Belowground C input 25% of assimilated C (based on Taghizadeh-Toosi et al., 2014)

Results – Sustainable straw removal rate

Total straw potential for bioenergy:
66 Mton dry matter
~1100 PJ

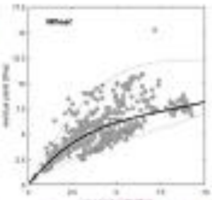
Current SOC stocks on arable land

Results – Straw potential per crop



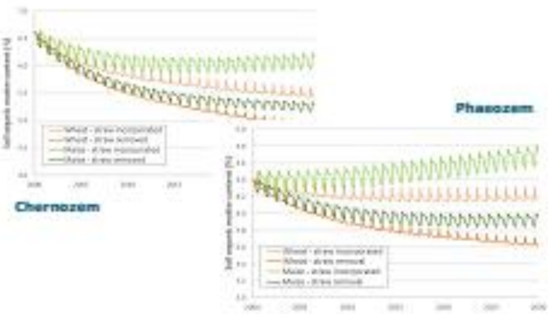
Discussion

- Low crop yields, less residues, risk on reduced soil productivity
- High soil carbon stock should be sustained with high C input
- Uncertainty is large, especially input of belowground C
- A field/farm specific tool should be used to assess the actual local potential



Source: Camia et al. (2018)

Effect of straw removal on SOC



Strategies to minimize soil quality loss

1. No-till planting – no ploughing
2. Harvesting straw only once every 2-3 years
3. Planting a green manure crop after harvest
4. Increase crop yields
5. Use stems, leaves for the soil (2/3 nutrients left in the field + 1/3 of organic matter)
6. Apply other organic fertilizers: digestate, manure, etc.
7. Better use maize straw not wheat straw
8. Returning ash from straw burning to the field
9. Requiring balanced fertilisation from farmers

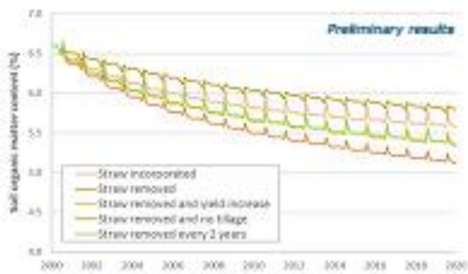
Strategies to minimize soil quality loss

- No-till planting – no ploughing
- Harvesting straw only once every 2-3 years
- Increase crop yield (based on yield gap)
- Better use maize straw not wheat straw

Approach for modelling effect strategies

- RothC model soil carbon model
- Case study for Vinnytsia oblast
- Two soil types:
  - Chernozem: 6.6% OM
  - Phaeozem: 4.4% OM
- Two crops:
  - Wheat: 5.2 ton/ha
  - Maize: 6.8 ton/ha
- Simulation for 30 years

Effect on SOC of straw removal scenarios



Conclusions

- The sustainable potential of straw for bioenergy is estimated at 60-70 Mton for the EU
- Sustainable removal rate ranges from 0 to 100%, depending on crop yield, soil and climate conditions
- Different strategies are available to avoid negative effects on soil quality

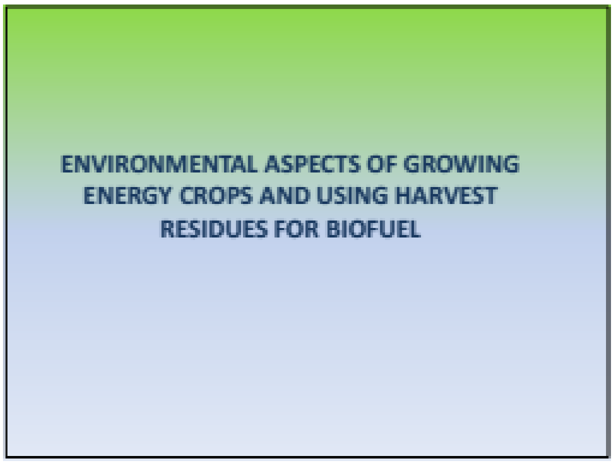
Recommendations

- Sustainable crop residue removal rates should be determined region and farm specific
- Strategies to reduce potential negative effects on soil quality need to be further quantified (both from soil quality as economic perspective)
- Long term soil carbon monitoring experiments are required to validate the effectiveness of these strategies

Thank you

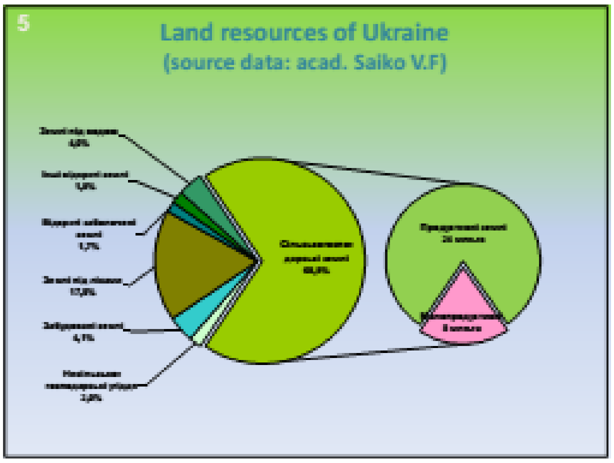
janpeter.lesschen@wur.nl

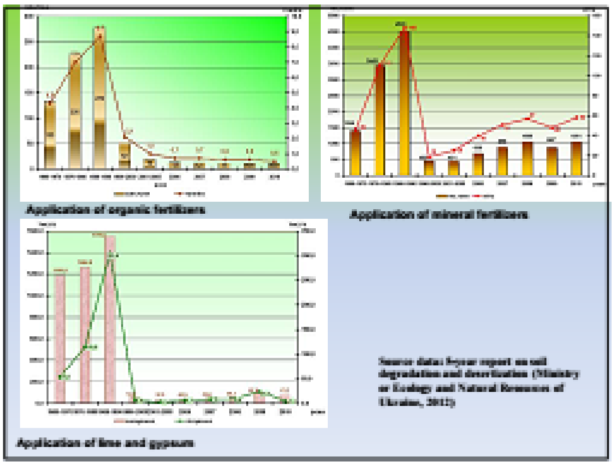
Mykola Royik (Institute of bioenergy crops and sugar beet of NAAS, Ukraine): Using residues vs using biomass crops for energy



Types and spreading of soil erosion in Ukraine

Type of degradation	% of arable land (32 mln ha)
Loss of humus and nutrients	43
Soil compaction	39
Silting	38
Water surface erosion	17
Acidity	14
Development of swamp	14
Radioactive contamination	11.1
Deflation and loss of topsoil	11
Pesticide contamination	9.3
Heavy metal contamination	8
Acidity, salinity	4.1
Water erosion and gulley formation	3
Silting of water bodies	3
[illegible]	0.35
Soil surface deformation by wind	0.35
Aridisation of soil	0.21
Land under construction	4.4





7

Losses of micro and macroelements when removing straw

Macro and microelements	Removal with 1 ton of straw* (kg a.i.)	Removal of nutrients with 17.7 mln ton** of straw, (1000 ton a.i.)	Compensation application of mineral fertilizers (1000 ton)	
N	5,5	97.4	Ammonia nitrate	278
P_2O_5	2.7	47.8	Superphosphate	239
K_2O	18	318.6	KCl	759
CaO	10.5	185.9	Limestone (88%)	232
MgO	5.1	90.3		
Si, Mn, B, Cu, Zn, S	0.25	4.4		
Total	42.05	744.3		1508***

* Winter wheat straw, 5% ash content (IBC&SB)

** According to the recommendations by [illegible]

*** Costs of compensation fertilizers UAH 11.4 billion

These costs will be enough for annual establishment of 163 000 ha miscanthus

8

Switchgrass and miscanthus as reliable protectors from soil erosion

9

Soil holding capacity of switchgrass root system

10

Powerful cluster roots of miscanthus

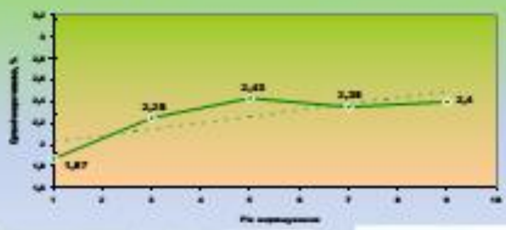
11

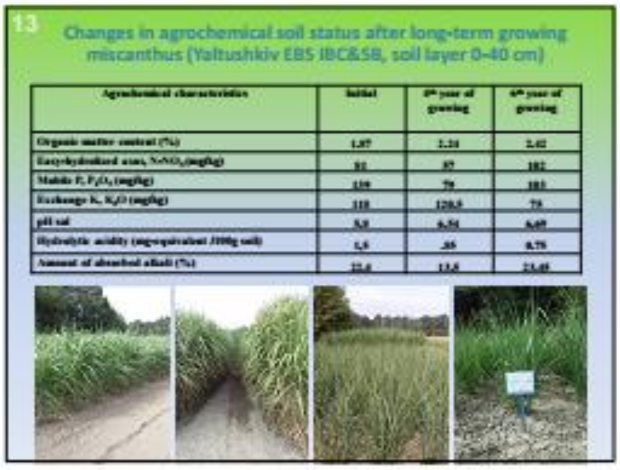
Changes in agrochemical soil status after long-term growing switchgrass (Yaltushkiv EBS IBC&SB)

Agrochemical characteristics	Initial 0-40 cm	Year of growing			
		3rd year of growing (0-40 cm)	5th year of growing (0-40 cm	7th year of growing (0-40 cm	9th year of growing (0-40 cm
Organic matter content (%)	1.87	2.28	2.43	2.38	2.4
Easy-hydrolised N, N-NO_3 (mg/kg)	81	77	68	65	128
Mobile P, P_2O_5 (mg/kg)	139	99	86	128	107
Exchange K, K_2O (mg/kg)	118	153	134	113	118
pH sal	5.8	4.94	5.16	5.38	6.81
Hydrolytic acidity (mg-equivalent /100g soil)	1.8	4.79	5.29	4.32	0.78
Amount of absorbed alkali (%)	22.4	17.79	17.8	18.2	23.5

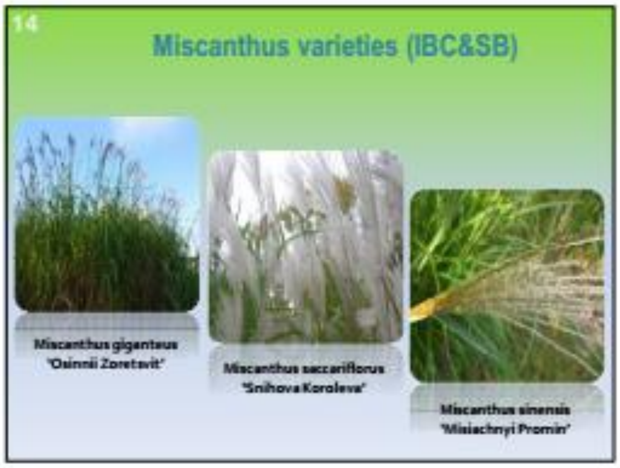
12

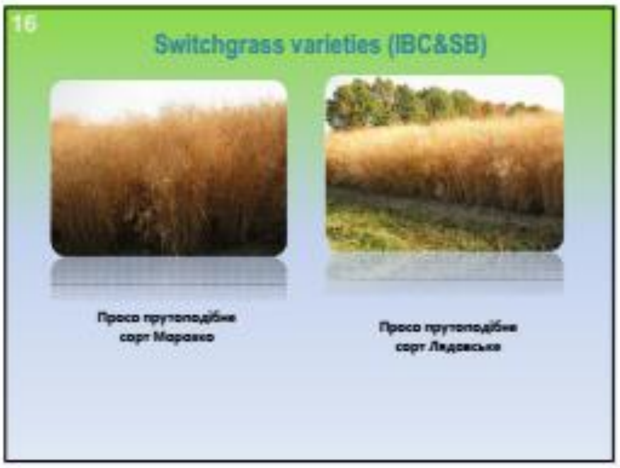
Dynamics of organic matter content in soil when growing switchgrass (2009-2017,Yaltushkiv EBS IBC&SB)





Agrochemical characteristics	Initial	[illegible] year of growing	[illegible] year of growing
Organic matter content (%)	1.87	2.24	2.42
Easy-hydrolized azot, N-NO3 (mg/kg)	81	87	102
Mobile P, P2O5 (mg/kg)	139	79	103
Exchange K, K2O (mg/kg)	118	120.5	73
pH sal	5.8	6.54	6.69
Hydrolytic acidity (mg-equivalent /100g soil)	1.8	.85	0.75
Amount of absorbed alkali (%)	22.4	13.8	23.48





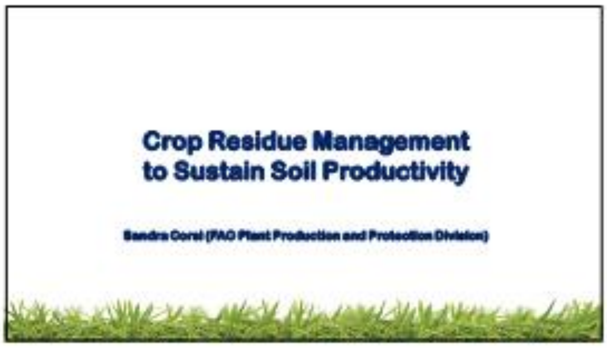
What is not ecological is not economical !!!

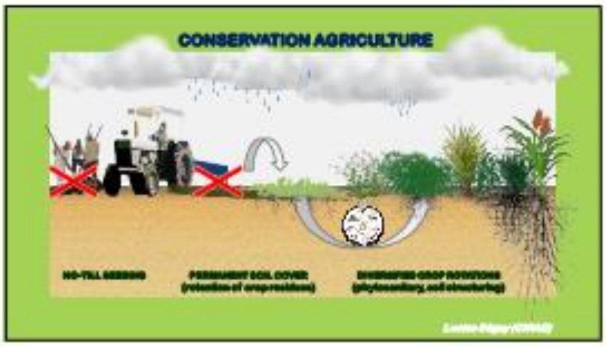
Thanks for your attention

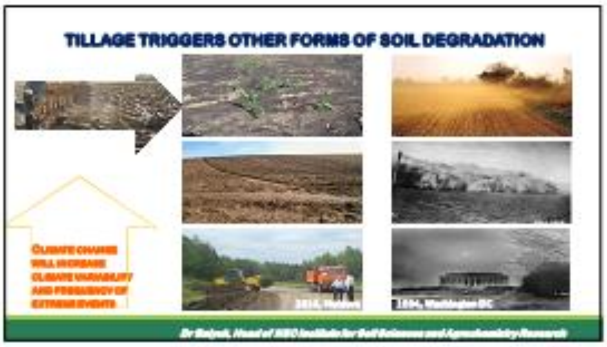
Dr. Sc. (Agric.), Academician of NAAS Mykola Roik

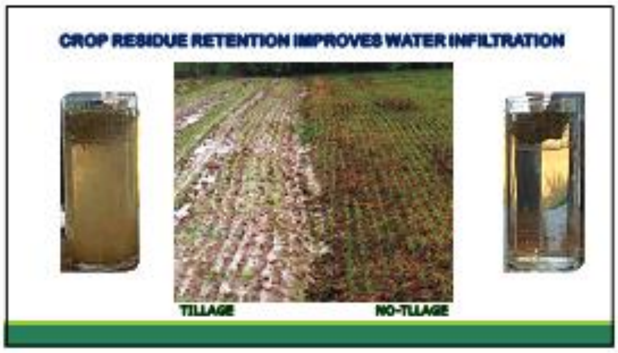
Director of the Institute of Bioenergy Crops and Sugar Beet
[illegible]
bio.gov.ua

Sandra Corsi (Food and Agriculture Organization of the United Nations (FAO), Italy): Recommendation from FAO on using agri-residues – Is Ukraine different?





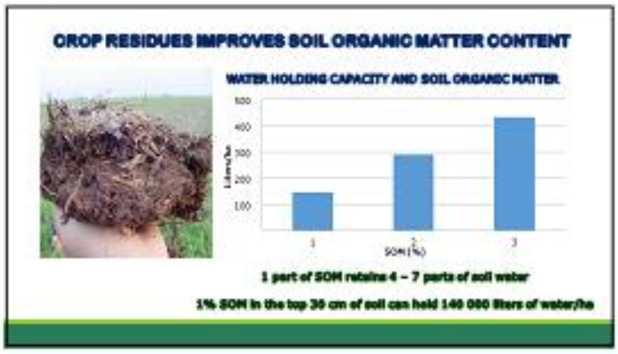


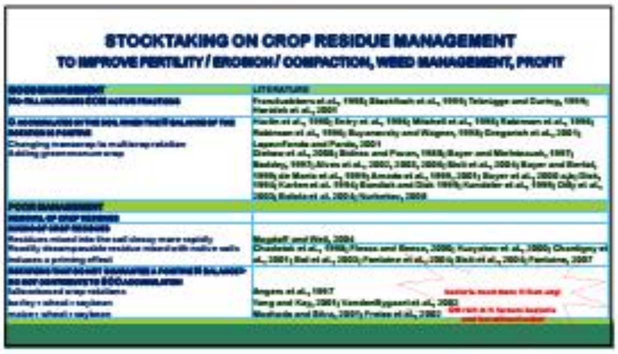

CROP RESIDUE RETENTION IMPROVES WATER INFILTRATION
TILLAGE
NO-TLLAGE


CROP RESIDUE IMPROVES CROPS' RESILIENCE TO DRY SPELLS
TILLAGE
NO-TILLAGE + COVER CROPS MIX


STUBBLE IMPROVES SNOW PRECIPITATION INFILTRATION


THE COST OF SOIL EROSION
VOLATILITY OF WHEAT AND CORN YIELDS
Wheat yield
Corn yield
DEVIATION FROM AVERAGE 1987-2012


CROP RESIDUES IMPROVES SOIL ORGANIC MATTER CONTENT
WATER HOLDING CAPACITY AND SOIL ORGANIC MATTER
500
400
300
200
100
1
2
3
SOM (%)
1 part of SOM retains 4 – 7 parts of soil water
1% SOM in the top 30 cm of soil can hold 140 000 liters of water/ha


STOCKTAKING ON CROP RESIDUE MANAGEMENT
TO IMPROVE FERTILITY / EROSION / COMPACTION, WEED MANAGEMENT, PROFIT
GOOD MANAGEMENT
LITERATURE
POOR MANAGEMENT

FROM BROAD PRINCIPLES TO SPECIFIC RECOMMENDATIONS - THE ROLE OF RESEARCH

Policy-makers and farmers need to have a clear indication of:

- How many crop residues need to be produced and retained on different soils to harmonize the use (removal) of crop residues with soil health (preventing erosion, maintaining soil carbon and controlling weeds)?

  E.g.: maintain SOC - equatorial tropics - 1.5 t of C/ha/year applied via crop residues
  3 t/ha/year of maize stover
  arid tropics - 2.5 t of C/ha/year applied via crop residues
  5 t/ha/year of maize stover
  temperate - 5 t of C/ha/year applied via crop residues
  10 t/ha/year of maize stover

- What are the return on the investments in the different agronomic practices / technologies?
- What are the behavioral changes that need to take place to improve crop residue management?

PARADIGM CHANGES DEPEND ON STRONG POLICY SUPPORT

TO RECONCILE SHORT TERM PRIORITIES WITH LONG TERM INVESTMENTS IT REQUIRES

COHERENT POLICY INCENTIVES THAT

ENSURE **SUFFICIENT INVESTMENTS IN INTEGRATED, MULTIDISCIPLINARY RESEARCH**

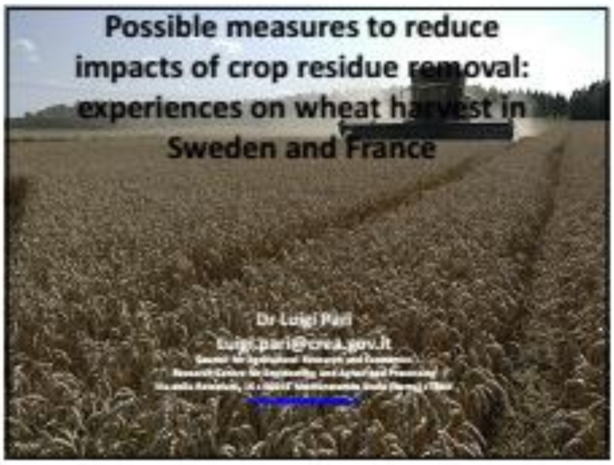
CONTACT DETAILS

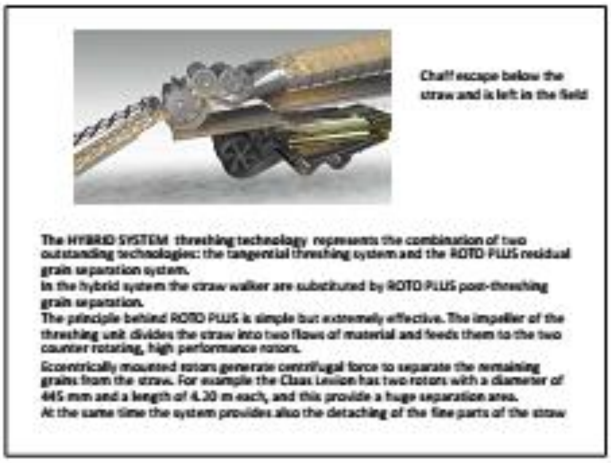
Sandra.Corsi@fao.org

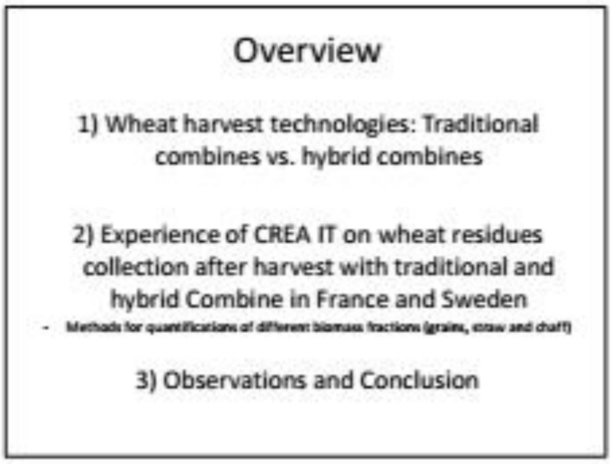
USEFUL RESOURCES

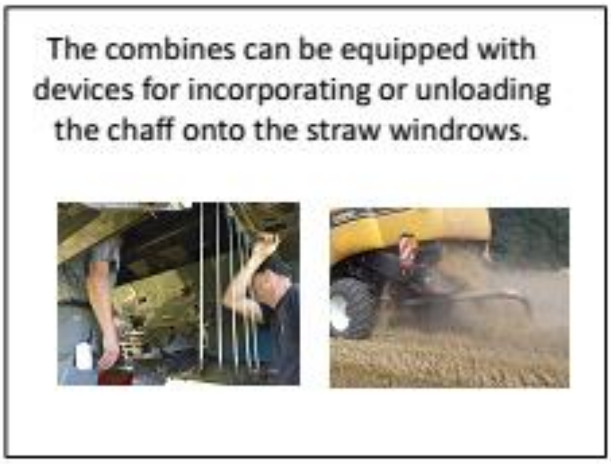
Sustainable Crop Production Intensification	Conservation Agriculture	Crop Residue Management
FAO Save and Grow [illegible]	**FAO Conservation Agriculture home** [illegible] **Conservation Agriculture crop rotations for eastern Europe & central Asia** [illegible] **Ukraine: Soil fertility to strengthen climate resilience. Preliminary assessment of the potential benefits of Conservation Agriculture** [illegible]	**Corsi, Friedrich, Kassam, Pisante, Sà, 2012. Soil Organic Carbon Accumulation and Greenhouse Gas Emission Reductions from Conservation Agriculture.** [illegible] **[illegible], Bogdanski, Tittonell, 2016. How does crop residue removal affect soil organic carbon and yield? A hierarchical analysis of management and environmental factors.** [illegible]

Luigi Pari (CREA, Italy): Options for harvesting straw of higher quality while leaving more nutrients behind









CREA IT Experience on residue collection in FRANCE

HARVEST TESTS PERFOREMD TO EVALUATE THE EFFICIENCY OF A TRADITIONAL COMBINE NEW HOLLAND CX840.

CREA IT Experience on residue collection in SWEDEN

HARVEST TESTS PERFOREMD TO EVALUATE THE EFFICIENCY OF A HYBRID COMBINE FENDT 9490 X

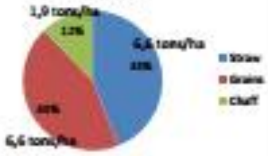
Productions

(all productions are reported in d.m)

Sweden

Sweden: on average 13,8 tons/ha of dry biomass were present in the field. Respectively the 51% was seed (6,8 tons/ha), the 37% was straw (5 tons/ha), and the 12% was chaff (1,7 t/ha).

France



France: on average 15 tons/ha of dry biomass were present in the field. Respectively the 44% was seed (6,6 tons/ha), the 44% was straw (6,6 tons/ha), and the 12% was chaff (1,9 t/ha).

Wheat residues: amount available of the different fractions

methods used for quantifications

PLOTTING

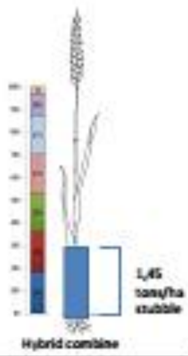
Biomass yield of the different fractions: separation of seeds, straw and chaf (part in the field and part in laboratory) to determine the yield per ha of each fraction.

Dry matter partitioning along the stem: determined on 100 stem samples, replicated 10 times. Each stem is divided in section of 10 cm and weighed with precision scale. The work allow to understand the amount of straw left as stubble after the passage of the machine (the study is matched with the post harvest measurement of the combine cutting height).

Straw: Dry matter partitioning

SWEDEN - **Biomass partitions along the stem:** Considering a total amount of 5 tons of straw potentially available in the filed, the 29% (1,45 tons/ha) remain in the field due to cutting height of the combine. The amount was calculated considering a mean cutting height of 16,3 cm (mean of 100 measurements) and through the study of the dry matter partitioning.

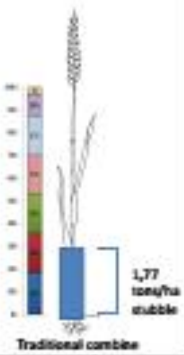
Material actually available for collection:
Straw 3,55 tons/h
Chaff 1,7 tons/ha
Total: 5,25 tons/ha



Straw: Dry matter partitioning

FRANCE - Biomass partitions along the stem: Considering a total amount of 6,6 tons of straw potentially available in the filed, the 26,9% (1,77 tons/ha) remain in the field due to cutting height of the combine. The amount was calculated considering a mean cutting height of 16,2 cm (mean of 100 measurements) and through the study of the dry matter partitioning.

Material actually available for collection:
Straw 4,83 tons/h
Chaff 1,9 tons/ha
Total: 6,73 tons/ha



In FRANCE with traditional combine and round Baler

Biomass left in the field after baling
On a total amount of 6,73 tons/ha of residues collectable, the biomass left in the field was 1,3 tons/ha (19,3%).

19,3 % of the material was left in the field

Quantification of the residues left in the field after baling

The material left in the field after the passage of the baler was quantified in both France and Sweden.

The combine and the recovery system used have influenced the amount of material effectively collected.

OBSERVATIONS

The combines used influenced the total amount of residues available for collection, with the hybrid system the collected product was only the 52%, while with the traditional combine the collected product was the 80,7%.

Therefore, with the hybrid system a significant amount of straw is left in the field, mainly the upper and thinnest part of the stem that pick up devices are not able to lift up

In Sweden with hybrid combine

Biomass left in the field after baling
On a total amount of 5,25 tons/ha of residues collectable, the biomass left in the field after baling were about 2,5 tons/ha (48%).

48% of the material was left in the field

CONCLUSION

The collection of the 52% of the residues achieved with hybrid combines can be considered a good compromise between "removed and left" organic matter from the field after wheat harvest and could be the way to balance the impact of residue removal.

Studies are needed to verify that the part left in the field would be the richest in minerals and nutrients to eventually take actions for adjusting the machines to reach this purpose.


Thank you for your attention
www.gruppo-panacea.it

Wolter Elbersen, Wageningen UR (The Netherlands): Formulation of conclusions

Wrap-up: highlights and conclusions from the workshop, explanation of follow-up.

Wolter Elbersen

Workshop “Agricultural residues for bioenergy. Problems and solutions”

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What is your standard?

A. Is you reference field burning and using natural gas? As it is now

B. Or is your reference maintenance of soil quality and energy crops as alternative energy source?

If we use field residues, A is now the standard.

This seems unsustainable soon → we need to make B our standard asap

“What is not ecological is not economical” or

“What is not ecological <u>should</u> not be economical”

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Group questions

- Assign a rapporteur
- Questions:
  1. Do we agree that agricultural field residues can be removed for other uses?
  2. How much? %
  3. What determines the fraction that can be removed?
  4. Is it clear how to do this? Are there question?
  5. What research needs to be done to solve the remaining questions?
  6. Who can carry out this research? What project do we need?

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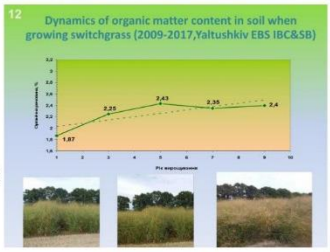
Can we have the biomass and feed the soil too?

- Yes, but it will cost extra
- Is it still competitive against alternatives like energy crops (natural gas)?
- We do not know at this moment!
- Can we define “no regret” recommendations?
- Can we define what we need to know and develop?



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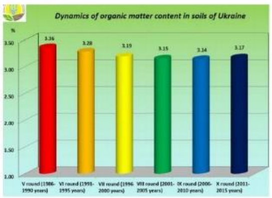
Where are soils in Ukraine now?

- Soils in Ukraine are declining –
  - Residue burning
  - Under-fertilisation
  - Lack of rotation
- Decline is slowing but still declining
- Using residues for energy seems not worse than burning straw in the field and using natural gas.....

Setting very high standards for crop residues may kill the option before it starts



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How promising are the measures?

Return Ash / digestate?

Better use corn than wheat straw

No-till + nutrient replenishment + rotation

- Arriaga: → higher yield?
- Lessche and E:
- No-till and straw removal is better than current practice without removal of straw

Tillage Type	Stover Yield	N Removal	P Removal	K Removal
	-- Mg/ha --	---------- kg/ha ----------		
	Moderate Harvest Level			
Conventional	4.1	~~24.0~~	2.6	31.9
No tillage	3.7	~~24.5~~	2.8	30.9
LSD (0.10)	ns	~~ns~~	ns	ns
	High Harvest Level			
Conventional	7.1	~~43.3~~	4.6	59.0
No tillage	7.3	~~49.7~~	6.0	63.8
LSD (0.10)	ns	ns	ns	ns

		Maize Residue Harvest Level		
	County Yield	No harvest	Moderate	High
	---------- Grain Yield in Mg/ha ----------			
Mean	10.2	9.8	10.1	10.1
Range	2.9 – 13.4	1.3 – 16.5	0.6 – 16.7	0.8 – 16.4

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How much field residue can we use without soil damage

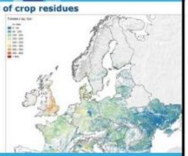
- 60 to 120 m Ha in EU.......
- 30 to 50% of residue

- How about Ukraine? 20 -30%
- Which 20/30%?

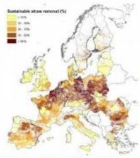
- In practice local residue will be (over)used.

Environmental potential of crop residues

The effect of residue removal rates on SOC stock change due to biomass removal



Results – Sustainable straw removal rate



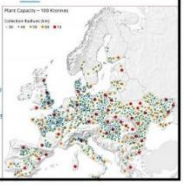
Total straw potential for bioenergy:
66 Mton dry matter
~1100 PJ

Plant locations

Map of potential plants

- Find most favourable site
- Establish plant capacity within a certain area
- Establish collection radius fo[r] a certain capacity

Optimal plant capacity depend[s] on available resources and collection costs



Time	Topic	Speaker
8:30 - 9:00	Registration and welcome coffee	
9:00 - 9:15	Opening of the Workshop	• Head of State Agency of Energy Efficiency and Energy Saving of Ukraine, Sergii Savchuk • Agricultural Counselor, Embassy of the Netherlands in Ukraine, Carolien Spaans • Regional Manager for Ukraine, Belarus and Moldova, IFC, Jason Brett Pellmar (tbc)
9:15 – 9:20	Introduction of moderator	Kees Kwant, Netherlands Enterprise Agency
9:20 – 9:50	The state of fertility of soils in Ukraine	Yuri Kryvda, Director of Cherkasy branch of State Institution "Soils Protection Institute of Ukraine" (Ukraine)
9:50 – 10:20	Sustainable use of crop residues for bioenergy: USA research	Dr. Francisco J. Arriaga University of Wisconsin-Madison Soil and Water Management Specialist
10:20 – 10:30		Break
10:30 – 11:00	Experience in the EU with sustainable use of crop residues for energy	Nicolae Scarlat, JRC
11:00 – 11:30	Agricultural residues for bioenergy. Problems and solutions	Jan Peter Lesschen, Wageningen UR (The Netherlands)
11:30 – 12:00	Using residues vs using biomass crops for energy	Mykola Royik, Institute of bioenergy crops and sugar beet of NAAS (Ukraine)
12:00 – 13:00	Lunch	
13:00 – 13:30	Recommendation from FAO on using agri-residues – Is Ukraine different?	Sandra Corsi, Food and Agriculture Organization of the United Nations (FAO)
13:30 – 14:00	Possible measures to reduce impacts of crop residue removal: experiences on wheat harvest in Sweden and France	Luigi Pari, CREA (Italy)
14:00 – 14:30	REACTIONS from panel	• Policy: Ukraine Ministry of agriculture: Policy view • Industry: Agro Holdings • Financial institutions • Bioenergy association of Ukraine
14:30 – 15:00		Break
15:00 – 16:00	Collaborative formulation of recommendations and research questions	4 groups will formulate recommendations and identify research priorities
16:00 – 16:30	Reporting per group + short discussion	Reporting by one rapporteur per group
16:30 – 16:45	Wrap-up: highlights and conclusions from the workshop, explanation of Follow up.	Wolter Elbersen, Wageningen UR (The Netherlands)
16:45	Closure of Workshop and Drinks	

We have a window to do the research now!

- No-till → Will this solve it???
- Harvesting straw only once every 2-3 years
- Green manure crop
- Increase crop yields
- Leaves for the soil (2/3 nutrients left in the field + 1/3 of organic matter) → Pari
- Apply other organic fertilizers: digestate, manure, etc.
- Use maize straw not wheat straw
- Returning ash from straw burning to the field
- Requiring balanced fertilisation from farmers

- Measure (soil) impacts
- Measure cost
  - what is value of SOM?

- Make the right comparison!
- Natural gas come at a cost: loss of foreign funds and security of supply and GHG emissions!

- Better have farmers make good (long term) decisions → give them the tools!
- Financiers can help by setting standards – but not kill the option
- Government can help with right compensation system

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END

Drinks.......

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