Mechanical analysis and investigation of the impact of climate change on crop production in different climate area

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Abstract

Climate change is already having an impact on agricultural production. This report presents a mechanical evaluation of the impact of climate change on crop production at the international context of agro engineering industry. In this report, we examined two countries and two climate regions: mountain area and central European climate in Transylvania (Romania) and central European plain climate area in Hungary. The test content is triggered by usage GPS in agriculture to improve efficiency and reduction losses, both in usage of fertilizers and pesticides. The analysis focuses also on transfer skills to inform the farmers' application of GPS in precision farming and sustainable farming. Fertilizer distributors were also tested in two different climate areas. The stages of the testing procedure: 1. Determination of the main physical properties of the fertilizer used 2. Flow-rate measurement 3. Spreading test.

Keywords: fertilizer distributor, spreading test

Introduction

The report focuses mainly on a mechanical evaluation of the impact of climate change on crop production at the international level, and it features an analysis of the situation in two country's agricultural regions where the negative effects of climate change are especially pronounced. The participating Universities, who carried out the tests: Hamk University of Applied Sciences at Mustiala in Finland and University of Debrecen, Faculty of Agricultural Sciences in Hungary and Stoas in Netherland and the University of Agriculture (USAMV) Cluj-Napoca in Romania?

Climates are different in the 2 tested countries: mountain area and central European climate in Transylvania (Romania), central European plain climate in Hungary (Hortobágy and Tisza region, Hungary).

This report contains an analysis of two regions. The central European region in Debrecen area in Hungary is a leading 'grain' region, a perfect example of the recent drought problem. The central European mountain area and climate in Transylvania (Romania), is a good example of a region that already experiences significant problems related to soil erosion by wind and water.

The modern agro-food sector has to meet society demands like food safety, sustainability and the aim that there should be enough food production. This implies the needs of high efficient use of nutrients in production processes (horticulture, crops, animal production). This includes low input farming / high output farming; cost price efficiency; reduction of environmental losses. High tech technology contributes to this efficiency. The development of high tech mechanics in agricultural equipment is a continuous process of innovation; both industry and research are stakeholders in this development process. Once applied in the agro food sector special companies and contractors with a highly specialized workforce deliver the equipment, services or contractor services to the primary sector (*Roseboom et al.* 2010).

Fertilizer distributor test method

There is network (ENTAM) that provides international standards to testing fertilizers. The ENTAM is a network of the official testing stations in those European countries which have signed an agreement on shared activities. The tests are based on national, European or international standards, or shared agreements (or methodologies), and can provide the manufacturer with useful information on ways in which to improve its machinery. The results may be issued as test reports published by the Testing Stations.

Factors influencing fertilisation:

1. Fertilizer: surface characteristics, grain (granule) shape, grain hardness, grain size range, specific grain weight
2. Environmental conditions: wind, humidity, uneven ground, relief (landscape type)
3. Human/Operator: ground speed, PTO (Power take off) speed, correct machine adjustment
4. Machine: type of spreading pattern, type of overlap, adjustability of machine, design of machine (working width, flow rate)

The most common potential conservation tillage techniques and strategies which reduce erosion by protecting the soil surface and allowing water

– No tillage: No-till leaves the soil undisturbed from harvest to planting.
– Ridge tillage: Ridge-till involves planting into a seedbed prepared on ridges. Residue is left on the surface between ridges.
– Mulc tillage: Mulch-till leaving around a third of the soil covered with residues after seeding.

Materials and methods

Precision agriculture technology was investigated in the two countries

1. At the University of Debrecen, Faculty of Agricultural Sciences in Hungary, a Trimble EZ-Guide 500 GPS guidance system was tested, and a Green Star automatic steering planting system was investigated.
2. At the University of Agriculture (USAMV) Cluj-Napoca in Romania an automatic steering system was tested, it was made by Trimble.

We can determine the following characteristics of fertilizer granule

Nevertheless it can not only be a high tech oriented course. It is important to set the existing equipment, especially the fertilizer distributors:

1. Particle size and particle size distribution,
2. Bulk density,
3. Moisture content,
4. The angle of repose.

Particle size and particle size distribution
Particle size and particle size distribution are determined with the aid of test sieves used under prescribed conditions, i.e. shaking intensity, amount of fertilizer and duration of shaking. The smallest and the largest particles are given with the proportion of the particles <1 mm and >4 mm in the sample (d<1%, d>4%).

Bulk density
A measuring tube of 1000 cm^3 capacity is used to determine the bulk density. The mass is measured with an accuracy of 0.1 g.

Spreading test
The fertilizer distributors were tested at University of Debrecen, Faculty of Agricultural Sciences in Hungary and at the University of Agriculture (USAMV) Cluj-Napoca in Romania. Generally the aim of the test method is different:

1. Preparing the manual for a new machine- mainly performed in large halls under laboratory circumstances (constant temperature, constant air humidity, etc).
2. Providing adjustment data for a new type of fertilizer.
3. Testing the spreading quality of a used machine.
4. Testing the machine when we need to change something (fertilizer type, amount of fertilizer, working width, etc).

The Test Method at the University of Agriculture (USAMV) in Transylvania (Romania):
The three test runs (Practice Test). Layout:

– Test area width: 3×track width.
– Test area length: 60–70 m.
– The three tracks must be parallel.

Perform a calibration test:

– Ground speed: select 3–4 km/h.
– Run over tracks 1 to 3 in succession.
– Open metering slide 10 m before the catch trays.
– Close metering slides approximately 30 m after the catch trays (*Hagymássy* and *Ancza* 2011).

The Test Method at University of Debrecen, Faculty of Agricultural Sciences in Hungary

– After repeating the test three times the boxes are collected and the quantity of theirs is measured with an accuracy of 0.1 g.
– The values are typed into a computer and with the help of a target software the computer determines the main qualitative characteristics of the spreading device (*Hagymássy* and *Ancza* 2011).

In Hungary 4 fertilizers were used during the tests:

– NPK 15-15-15 (Agrolinz Agrotechnikalien GmbH).
– Salt of Linz (ammonium nitrate limestone 27% N, Agrolinz Melanin GmbH).
– Potash (0-0-60%, Tiszamenti Vegyiművek, Szolnok).
– Ammonium nitrate (34% N, Nitrogénművek Rt., Pétfürdő).

To characterize the transversal unevenness of spreading, we use the coefficient of variation (CV). The definition of the unevenness of spreading gives CV as the variety factor.

$$CV = \frac{100}{\bar{x}} \sqrt{\frac{\sum_{i=1}^{n} \left(x_i - \bar{x} \right)^2}{n-1}} \quad (2)$$

where: x_i the average amount of collected fertilizer at a certain test place during three measurements; $\bar{x}$ – the average amount of collected fertilizer at all test places during three measurements; n the number of test places (*Csizmazia* 1993).

Results and discussion

Precision agricultural techniques which reduces the impact of climate change in Transylvania and in Hungary

The GPS guidance system and the GPS automatic steering system were tested. Precision agriculture technology was investigated in the two countries. Field computers have been developed to improve virtually every farming function from variable rate applications, auto-steering, automatic boom height and section controls, planter controls, yield monitoring. According to our tests innovation and information management systems reduce operating costs, precisely control inputs and improve the quality from automatic steering to automatic planting systems (*Figure 1*).

Figure 1. *The Trimble EZ-Star GPS automatic steering system was tested at University of Agriculture (USAMV) in Cluj-Napoca in Transylvania*

Determination of the main physical properties of the used fertilizers; the stages of the procedure:

– Determination of the main physical properties of the fertilizer used.
– Flow-rate measurement.
– Spreading test.

1. Determination of the main physical properties of the fertilizer used:
   The main objective of this operation was to draw attention on the differences of physical properties of fertilizers that we use and those in the manual even if the types are the same, and on the necessity to check them and then to use the results in the setting procedure.
2. Flow-rate measurement:
   The bulk density (kg l^{-1}) of the Ammonium nitrate was measured and as it was definitely different (0.88 kg l^{-1}) from the bulk density of the Ammonium nitrate in the manual (1.05 kg l^{-1}), students had to modify the setting data given in the manual. The required application rate was 200 kg ha^{-1}.
3. Moisture content:
   The moisture content is measured according to the international standard, with three repetitions: the mass of the sample is 25 g, the temperature inside the drying apparatus is 103+1 ºC; the duration of drying is 72 hours. The mass of each sample is measured with an accuracy of 0.1 g

Spreading test at University of Agriculture (USAMV) in Cluj-Napoca, in Transylvania (*Hagymássy* and *Ancza* 2011)

Details given in the spreading charts obtained using fertilizer with ideal physical characteristics. Relevant technical spreading characteristics of fertilizer can vary, even with the same type and brand. Manufacturers provide a practical test kit which offers an in-field simple and quick method of checking spread patterns. This means greater assurance of constant accuracy during spreading and increased precision. The spreading test was carried out on a field on the Experimental Research Facility of the University. Students worked in groups of 4 people. Before starting the test they had to adjust the machine (hoper height, vanes, metering slides), according to the instructions given in the manual. The actual working width was 15 meters and 6 catching trays were placed on the overlapping zone of the spreading. GPS equipment was installed in the tractor to help following the tramline and keeping the working width (*Csizmazia* 1993).

Evaluate the results and correct if necessary:

– Collect the contents of the trays and pour them into the measuring pipe from the left.
– The quality of the cross-distribution can be easily read from the fill level of the three sight glasses.

Possible results of pass:

A: The same quantity is in all tubes (permissible deviation±1 graduation): Adjustments are correct.
B: Asymmetrical fertiliser distribution.
C: Too much fertiliser in the overlap zone
D: Too little fertiliser in the overlap zone.

Depending on the spreading width, determined by the parameters of the applied spreading device, we can use the measuring track up to 40 meters width. The transversal spreading pattern was determinate, the maximal and the optimal working width were determinate, available with the given fertilizer and with the given adjustment simulation of border spreading (*Hagymássy* and *Ancza* 2011).

Figure 2 shows the real conditions during the test procedure. Two students are staying in the cabin of the tractor at the same time. One of them is driving the tractor while the other one is checking the operation of the GPS (*Hagymássy* and *Ancza* 2011).

Figure 2. *The Rauch MDS 935 fertilizer spreader during the testing procedure at University of Agriculture (USAMV) in Cluj-Napoca in Transylvania*

Spreading test in Hungary

The standard spreading test procedure was in Hungary. The test field at University of Debrecen, Institute for Land Utilization, Technology and Regional Development:

Our test field in University of Debrecen consists of a 50 m long concrete track where the machine can speed up to the speed of operation. Perpendicularly to the track there is a 42 m wide steel frame into which the measuring trays can be placed. During the test the machine passes over the trays due to the movable cantilever beam which is drawn by the tractor (*Hagymássy* and *Ancza* 2011).

The measuring track capable perform was out-door measurements, and so during the examinations we try to eliminate the effects of external influences (irregularities in field surface, together with inclination of terrain, the wind, etc)

The fertiliser spreader can be attached to the three point linkage system fitted up the cantilever beam. The discs are driven by the PTO.

The opening and closing of the metering device is solved from the tractor, either mechanically or hydraulically. With the cantilever the fertilizer distributor can move up to 3 meters beyond the line of trays.

The area of the measuring trays is 500 mm square. Their shape is a truncated pyramid and they are equipped with grids to prevent the fertiliser particles from popping out. The measuring trays are placed along the entire spreading width and under each tray there is a numbered box, where the fertiliser particles are collected. The line of the trays is raised above the ground.

After each measurement three diagrams are given:

– The transversal spreading pattern was collected, in which the mass of the fertiliser in each measuring box is plotted, in grams. The number of the measuring boxes is determined by the spreading width, expected in the given adjustment with the given fertilizer type (*Hagymássy* and *Ancza* 2011).
– The spreading curve shows the unevenness of spreading in the function of the working width. According to the diagram, without overlapping, the spreading width is equal to the working width. In this case the unevenness is the largest. Increasing the overlapping per meter the working width and the unevenness will decrease. As a result, on the basis of the diagram we can determine the largest working width, at which the unevenness remains under CV=15%. The spreading diagram was made and the transversal spreading pattern with the maximal working width was determined (*Figure 3).*

Figure 3. *The fertilizer spreader during the testing procedure at University of Debrecen Institute for Land Utilization in Hungary*

Tillage techniques which reduces the impact of climate change in Transylvania and in Hungary

According to our tests in Transylvania the goal is minimizing water and wind erosion and increasing soil fertility. According to our tests in Hungary the goal is protecting the soil surface and allowing water to infiltrate instead of running off, and increasing soil fertility. Reduction of the effects of wind erosion and the costs of the tillage and sowing as well as energy savings aspects led to combined tillage and sowing machines, which have multiple versions. One of the advantages of these devices is that they do not change soil structure, do not destruct capillary routes which results in the longer preservation of moisture compared to a ploughed area. Following ploughing furrows are created which conduct water towards the direction of the slope, where it might accumulate and cause damage.

It requires further investigation as to whether any other conservation tillage practices are adequate, because no one conservation tillage method is best for all fields.

Conclusions

We conclude that central European agriculture is vulnerable of the effects of climate change. In addition, agricultural companies are also poorly equipped, mainly in Romania to withstand the negative effects of climate change. While all leading grain-producing regions in Central Europe were affected by the drought, the impact was more widespread. Further modernization of the industry, with a transition to innovative technology, will reduce the degree of its dependence on weather conditions and will correspondingly increase production.

In this report, fertilizer distributors were examined also, because examinations can provide useful information on ways in which to improve its machinery. The end-users of the high tech applications are farmers and contractors. The circumstances, including climate, are different in the 2 tested countries. But the applications of agriculture mechanization are comparable, and the adequate mechanically evaluation is analogous and comparable.

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