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Agricultural engineering in the ecological mountain farms

Abstract: Mountains and hilly regions in Poland are very important for Polish economy because they do not only account for 8% of Polish territory, but also fulfil a significant role in environmental protection of water supply for the rivers, in tourism and in the ecological chain of plants and animals. The best type of agriculture for such areas is organic farming, which obliges farmers to minimize biological degradation of agricultural lands while allowing to obtain products of highest quality. For proper management of organic farms farmers need specialized machinery and necessary infrastructure. Machinery must fulfil specific requirements, such as safety of work, small overall dimensions and mass, surplus power and reliability. In the first part of the paper specific requirements will be discussed for such machinery as tractors equipped with various cultivation equipment, transport vehicles etc. In the second part we will provide a survey of tractors, machines and equipment produced in Poland, with indication of the development directions.

Key words: ecological farming, mountain regions, agricultural machines, grasslands, transportation

Introduction

Mountains and hilly areas in Poland cover up to about 25,000 km², accounting for almost 8% of the total area of the country.

Mountainous areas in Poland are situated within three basic physiographical units:

- in Carpathian Mountains (roughly 17.5 thousand km²);
- in Sudeten Mountains (roughly 5.0 thousand km²);
- in Holy Cross Mountains (roughly 2.5 thousand km²).

According to the Polish Law Official Journal No. 158/2004 the altitude above sea level is the main criterion describing the mountainous regions in the country. In accordance with this criterion mountain areas, classified at the level of the basic administrative unit, the commune, have been divided into:

- *piedmonts* – where at least 50% of the commune's total area is situated 350 m above the sea level;

- *mountains* – where at least 50% of commune's total arable land is situated 500 m above the sea level.

The main challenge for these regions is to ensure and protect water resources for the whole country. Both heavy precipitation (1.5–2.5 of national average) and a great number of river or torrent heads make out of the mountain areas the major water reserve, accounting for about 30% of total water resources of Polish rivers (Kopeć, Pływaczyk 1997).

That is why every economic activity carried out over there should treat problems of water purity protection as priority. This concerns, in particular manner agriculture, because farms and arable lands cover about 50% of the mountainous areas.

Agricultural production in mountain regions should not cause biological or physical deterioration of arable lands. Mineral fertilizers and plant protection chemicals should be excluded from agricultural production process in that area, as they are the major source of water pollution. Hence, agricultural production in the mountains should be based on organic or ecological methods and principles that forbid utilization of chemicals.

On the basis of results from respective investigations the principal trends for ecological mountain farm development have been outlined. It has been proved, in particular, that growing of cereal crops and potatoes on the mountainsides increases water erosion of soils to a higher degree than growing of grasslands or forests. It is therefore recommended to develop in these areas organic dairy and meat farms based on fodder produced on their own.

The present paper refers to problems of mechanization on these farms.

Major requirements for machines in ecological mountain farms

Due to physiographical conditions of mountain regions in Poland every agricultural machine working in these areas should meet specific safety requirements. In comparison with machines working in lowlands, those functioning in the mountains should be characterized by:

- smaller size;
- smaller mass and capacity;
- lower center of gravity;
- lesser working width;
- secure braking and coupling systems;
- reliable driving power.

Taking into account the possibility of utilization of agricultural implements, mountain terrains have been divided into three exploitation zones (Jucherski, Walczowski 1991):

I zone – slope angle up to 12°

II zone – slope angle from 12° to 15°

III zone – slope angle from 15° to 25°

In the Ist zone, traditional agricultural tractors may be the source of driving power. In the IInd zone, where grasslands predominate, working aggregates should be based on modified tractors providing double axle drive, lowered ground clearance, increased wheel track, possibility of wheel twinning and additional loading of front axle. Loading capacity of the aggregate should not exceed 2 tons.

In the IIIrd zone, where there are grasslands only, mechanization of operations is ensured by special energy means:

- self-propelled tools carrier 4K4 (four wheel drive) for grass mowing and hay making with possibility of grassland cultivation and fertilization;
- self-propelled agricultural vehicle 4K4 equipped with replaceable machine bodies of 2 ton loading capacity for grass harvesting and transporting as well as for fertilizing and farmyard works.

In the upper parts of the mountains one can use one-axle self-propelled moto-tools only enabling grass mowing and tending, as well as carrying out different farmyard and cultivation works.

The above mentioned machines have been utilized in Western Europe for decades. In Poland, their development was slowed down in the early 1990s because of the breakdown of agricultural production in the whole country and especially in mountain areas.

Nowadays, ecological degradation of mountain areas in Poland is still significant. The situation can not get better unless agricultural technology and engineering for mountain areas are properly developed. In the Polish mountainous landscapes for many years already an increasing share of not mown grasslands has been observed. This has brought their degradation in terms of potential use. There are also lesser cattle in grazing meadows of former grasslands within the upper parts of the mountains.

Agricultural machine market for ecological mountain farms

Self-propelled carriers

Two-axle drive (extra drive of front axle) is the basic requirement that tractors or self-propelled machines working in mountain areas should meet. Front axle drive involves the increase of tractor's towing power efficiency. After the drive is engaged the tractor's traction power increases by 20 up to even 49% (Jucherski *et al.* 1988; Król *et al.* 1988). Increased driver safety in the vehicle version 4K4 on slopes is achieved due to the reduced sliding of even 54% of

aggregate's driving wheels when they are going up the slope and of 40–57% when they are going down the slope.

Application of the front driving axle in the tractor causes reduction of braking distance (by almost 54%), and makes possible changing the aggregate driving direction at a smaller turning diameter. As a result, the engaged double axle enables achieving both higher traction efficiency and higher surface capacity of the tractor at lower fuel demand in comparison with a tractor whose front axle drive is out of work.

Other important advantages of an extra front axle drive are better driving stability and easier manipulation of the vehicle, both of which result from the reduced sliding and more efficient braking. These factors are decisive as regards driver safety and comfort. Moreover, there is also improved agricultural protection of soil during cultivation measures. Wheel sliding causes total destruction of soil surface structure and plant root system over the area where it occurs, and it also unfavourably affects the process of soil fertility restitution.

Taking into account the energy aspect, power of tractor engines amounting on the average to 35 kW (occasionally to 50 kW) is sufficient to carry out full range of measures in a typical mountain farm of 50 ha of arable land.

The final ecological criteria for machine design are as follows: similar wheel size for both front and back axle, reduced pressure in tires, which in some constructions should not exceed 0.08 MPa, the same wheel track of aggregates - to keep the same trace. The last factor enables the reduction of the area of compacted soil layer.

Ideal "mountain" design requirements include high loading and power capacity at low total weight of the aggregate, bigger tire diameter at reduced pressure and necessity of keeping work stability, which depends on the angle of the vehicle's construction cross balance. These requirements are not easy to meet, especially when the construction is to be a universal technical solution complying with the necessary functions of energy implement and machine aggregate as well.

You can find compromise solutions in the special mountain self-propelled mower and swath turners. They are fitted with engines of suitable power, high safety parameters and work quality, and, moreover, they feature lightness and maneuverability. Application of the low-pressure tires (31x15.50-15xTR) of TERRA type (which are not useful for driving on hard surfaces) affects in a small degree only the bed covered with lichens, at the same time keeping all traction advantages in these conditions.

That is why fitting modern tractors with wide tires becomes the obligatory construction standard. It is very important, especially when tractors work in mountain conditions, because wide tires increase their traction abilities (reduced sliding), and reduce the risk of side slips when the aggregate works along the slope. Total weight of vehicles should not exceed 3500 kg (tractors) and 1500 kg (self-propelled energy implements – the so-called machine carriers).

A quite rich national tractor offer enables selection of the proper machines for purposes of mountain agriculture and all these machines being suitable for grasslands:

- Low power tractor (31 kW) SOLARIS Wind 4K4 equipped with the frontal tri-point linkage (TUZ);
- Tractor ŻUBRON 2048 A 4K4 of 33 kW power and of 1500 mm wheel track;
- Tractor ZETOR 3321 4K4 of 33 kW power.

When the works with higher power demand are to be carried out (for example mowing or manure spreading) the tractors ZETOR SUPER EKO 5321/41 4K4 and ZETOR SUPER 4K4 of 46 kW power, or tractor URSUS 4514 of 48.5 kW power can be used. In these tractors wheel tracks of the front and rear axles can reach 1800 mm of width (in URSUS the width of the rear axle reaches even 2210 mm), which increases tractors stability on slopes. Due to the suitable power resource these tractors can be used for energy-consuming technological operations in difficult conditions and ensure the operator's safe and good working conditions.

Tractors designed for ecological mountain farms should be fitted with frontal TUZ (three-point linkage) and power take off shaft (optionally), enabling simultaneous frontal and rear mounting of implements and creating multifunctional aggregates which, in turn, enable significant reduction of operation numbers.

In the Alpine countries, where grasslands are also cultivated on steep slopes of 16-20°, farmers have at their disposal two types of self-propelled equipment:

- two-axle mowers being the carriers of mounted and trailed machines for mowing, tending and raking of grass and hay (Jucherski, Król 1998);
- agricultural multifunctional vehicles for mountain farming, which are adjusted to carry the exchangeable equipment as for example self-loading semi trailers for forage and hay, manure spreaders, slurry tanks, semi trailers or other mobile equipment applied in the mountain breeding farms.

Despite the improved production of mountain agricultural machinery, Polish farmers are still interested in simple units fitted for use in their farms, like, for example, machines produced by "Agro-Partner" in Cracow. This company has implemented agricultural technique for mountain farming (Burkiewicz 2002) and it also offers tractor-machine units as well as simple machines produced by the Italian enterprises BCS SpA, DURSCO, CAEB.

Some of these machines were designed in the early 1970s, like, for example, mowers BCS. At that time they were tested and evaluated by scientist in research station in Carpathian Mountains (Tylicz, Poland). According to the researchers' opinion these machines were not very useful for high grass crops, which were then being achieved on mountain grasslands in Poland.

To sum up, machine units for mountain farming, together with their self-propelled carriers are still very useful for Polish mountain farms, and due to their

multifunctional utilization they are especially recommended for the ecological farming.

Transportation

The long term of Institute for Building, Mechanization and Electrification of Agriculture investigations carried out at Tylicz have shown that in mountain agriculture, maximal loading capacity of trailed machines for transportation, fertilizer application and harvesting operations – combined with tractors of 9 KN – should not exceed 2000 kg, with total machine weight amounting to 3500 kg.

Due to the advantageous transport and machine parameters it is recommend to use the combined unit consisting of tractor 4K4 (or its modified version for mountain purpose) linked to the single axle mounted machine fitted with tires of 10” wide and 15” diameter, by the aid of a quick pick-up hitch. The front wheel traces of the aggregate should follow the rear wheel traces.

In the present economic situation agricultural activity on the area of sloping relief (inclination angle $>15^\circ$) should not be intensified. However, if the agricultural measures are carried out there, and mountain-oriented self-propelled machine carriers need to be used, loading capacity of the one-axle machines combined with them should be reduced to 1000 kg because of safety considerations.

The technological carriers NG-2 combined with tractors keep the standard limitation of 2 tons of maximum loading capacity. These carriers have been fitted with changeable semi-trailers-machines, including tipping trailers and manure spreaders.

The technological concept of the aggregate based on a self-propelled carrier 4K4 fitted with one-axle trailed machine has been implemented with the unit consisting of one-axle carrier NG-1 with basic semi-trailer, manure spreading adapter (1000 kg) and tipping trailer (1000 kg). In the presently available offer of machines the carriers NG-1 and NG-2 are replaced by the one-axle machines for different purposes.

Fertilizer application

In organic farming compost is the most important source providing soil with necessary nutrients. Manure should be the main component of compost in ecological farms. In order to ensure good conditions for the fermentation and ripening process, manure should be laminated in the form of a pile with intermittent layers of soil mixed with rock flour containing micronutrients, inedible green mass and other organic wastes.

In order to make compost production easier it is recommended to apply one-axle manure spreader of 2000 kg loading capacity equipped with narrow strip adapter fitted with special protective cover, which, during machine unloading, will play

the role of a screen for formation of the pile. Composting material should be previously prepared in the dung gutter.

For spreading compost over soil or green growth the one-axle manure spreaders of the type N-245, N-248 and N-226 can be used, with adapters equipped with horizontal rollers of 2000 kg loading capacity (2500 kg at most) manufactured by “Cynkomet” at Czarna Białostocka and “Warfama” at Dobre Miasto.

Mountain soil requires dolomite lime fertilizers enabling restoration of its proper acid reaction. Application of fertilizers can be effected by the use of conventional mounted or trailed spreaders, but the trailed ones should be exploited according to the rules obligatory for aggregates consisting of a tractor and one-axle trailed machine.

Application of fermented liquid manure may be done using one-axle slurry tank of 2000 – 2500 litre capacity equipped with disc spreader, centrifugal spreader or side sprinkler - depending on the system of tank unloading. To ensure safe exploitation, special barriers should be installed inside the tank, absorbing the liquid striking effect when the aggregate moves up and down (abrupt change of slope inclination angle). The existing offer of commercially available slurry tanks for ecological mountain farms is very poor. Practically, there is only one available slurry tank T-507/2 produced by POLMOT company at Chojna. This tank's capacity amounts to 2500 litre, but it does not fulfil all the “mountain” requirements (like, for example, internal barriers or side sprinkler).

For application of liquid organic manure in the mountains one can also use slurry tank PN-30 produced by MEPROZET Kościan, the experienced producer of agricultural equipment (in particular, the carrier NG-2).

The offer of one-axle spreaders for application of lime and mineral flour on grasslands and pastures is also rather poor, because it actually consists of one type equipment only – i.e. RCW-2 of 2.5 ton loading capacity, turned out by FMR Brzeg. There is, however, a very wide range of mounted spreaders of 200 – 400 ton loading capacity. As these machines require frequent manure loading it is necessary to arrange manure storage on site.

Sowing and planting

Besides the above described general rules of exploitation of agricultural treatment units there are no other special “ecological” requirements for the sowing and planting machines. Reduction of operational passages, application of combined - simultaneously working machines and tools units, as well as limitation of plough operations on slopes of 8–10° constitute main rules of exploitation of agricultural machines in the mountains.

On the Polish market of agricultural machines there is lack of a drill for direct grass sowing with disc coulter, enabling grassing and restitution of grasslands. Recently, such a drill was implemented as designed by Institute for Building, Mechanization and Electrification of Agriculture in cooperation with Agricul-

tural Research Institute in Kirov (Russia). It should be combined with a carrier of 9–1.4 kN. Another machine of a similar type is the imported drill S 184 (1.2 SPORT) of 1.2 m working width.

As Polish regulations insist on feed balance within an ecological farm, a part of arable land of a mountain breeding farm should be assigned for growing of cereal mixtures being the basic resource of own nutritive fodder and litter straw for animal stands. Then, this straw will be the basic component of manure compost.

National offer of drills for ecological mountain farms includes, in particular: the drill SO96 and S107 made by MEPROZET from Międzyrzecz Podlaski of 1.85; 2.5; 2.87 m working widths, respectively, as well as drill S025/3 made by FMR FAMAROL Słupsk of 2.7 m working width. Due to their small working widths these drills are suitable for driving in narrow field roads.

For potato planting two-row potato planters can be useful, like, for instance, those made by BOMET of 1.35 m working width or REMPRODEX Człuchów of 1.50 m working width.

Crop cultivation

Agricultural units for crop cultivation in mountain conditions should be of as small weight as possible and that is why it is very important that mountain ecological farms have light tractors. Such tractors may be combined with, for example, 3-5-section mounted tiller (ridger) P463, P463M made by RSP Kielce or OCZ-3, OCZ-5 made by AGROMEX Łuków; P420 made by PUPH Solec-Zdrój and P468, P468/1 made by ASPIL Pilzno.

It is recommended to use for potato cultivation the all-purpose trailed cultivator of 2.7 m working width, made by AGROMET Jawor, or weeder harrow (Ackerbürste) P466 of 4.2 m working width, made by Zakład Produkcyjno-Handlowy Syców.

In ecological farming plant protection is effected by biologically active substances of plant or animal origin and by other means involving compounds allowed in ecological farming and listed by the respective certifying unit in its legal documents and guidelines.

Water solutions of these substances may be applied and dosed using mounted crop spraying machines of 300–400 dm³ capacity, as for example PILMET412LM made by FMR-PILMET Wrocław or PROMAR Sadowno, and many others.

Summary

The research work on agricultural techniques for mountain areas was practically given up in Poland in the early 1990s. In comparison with the Western European countries, Polish mountain agriculture is poorly equipped with technical means,

and this fact has brought the agricultural degradation of mountain areas. The development of Polish mountain agriculture should be focused on organic farming. Ecological agriculture provides for landscape protection and soil fertility, and ensures protection of water resources purity. Sheep and dairy cattle breeding seem to be the most favourable orientation for ecological mountain farming development. The implementation of this orientation requires, though, a suitable technical base. Currently, lack of appropriate combined tractor-machine units and multifunctional aggregates with self-propelled tool carriers for mountains farming is especially acutely felt.

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