*Геник Я.В.* **Критерии оценки эффективности фитомелиорации нарушенных экосистем**

Предложены критерии оценки эффективности ведения фитомелиоративных работ. Раскрыты основные признаки правовой, экономической, технологической, биологической, экологической и социальной оценок эффективности процесса фитомелиорации нарушенных экосистем и мероприятий по восстановлению продуктивных биогеоценозов.

***Ключевые слова:*** фитомелиорация, восстановление нарушенных экосистем, оценка эффективности фитомелиоративных мероприятий.

*Henyk Ya.V.* **Criteria for evaluation of effectiveness of phytomelioration of damaged ecosystems**

Criteria for evaluation of effectiveness of phytomelioration activities are suggested. Main features for legal, economic, technological, biological and social evaluation of effectiveness of the process of phytomelioration of damaged ecosystems and activities for recovery of productive biogeocoenoses are described.

***Keywords:*** phytomelioraton, recovery of damaged ecosystems, evaluation of effectiveness of phytomeliorative activities.

***УДК 631+662.767.2***

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# POSSIBILITIES OF CULTIVATION AND USE OF SORGHUM AND SUDAN GRASS HYBRIDS (*SORGHUM BICOLOR* (L.) MOENCH) AS A BIOGAS SOURCE IN NORTH-WEST POLAND

The results obtained from field experiment showed that Sorghum (*Sorghum bicolor*) as well Sudan grass hybrids (*Sorghum bicolor × S. sudanense*) can be successfully cultivated on the light sandy soils of the Szczecin Lowlands and can enrich the group of plants cultivated for energy purposes, in particular for the production of silage for biogas plant. This was confirmed by the high fresh and dry mass yields of both species (Sorghum and Sudan grass) achieved at the Agricultural Experiment Station of the West Pomeranian University of Technology in Szczecin in 2011 and by high potential of yield of biogas and methane possible to obtain from one hectare.

***Keywords:*** Sorghum, Sudan grass, maize, biomass yield, yield of biogas and methane, West Pomerania / north-west Poland

**Introduction**. Sorghum (*Sorghum bicolor* (L.) Moench.) is one of the most important cereal plants (grain Sorghum) and is currently in the fifth place worldwide (after wheat, maize, rice and barley) with regard to surface and harvests **[**1**]**. It can be used not only for food for human, also for alcohol and beer production (grain and stem) and as feed and fodder for animals (fresh, hay, silage), and as energy plants for biogas production (whole ensilaged plants). It is an annual spring short-day and stenothermic plant (sprouts only at a temperature of >10 °C). It belongs to the plants using the C4 photosynthetic pathway and is cultivated on weak soil complexes due to its low soil requirements and high drought tolerance **[**2**]**.

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In north-west part of Poland (West Pomerania) dominates sandy soils (light soils) and not favourable climatic conditions for the cultivation of stenothermic plant species, e.g. maize. According to Koźmiński and Michalska (2000) **[**3**]** the average annual air temperature is of about 8,1 °C and the annual precipitation in the surroundings of Stargard Szczeciński (study area) fluctuates between 500 and 550 mm in the multi years 1961-1994. The region is characterized by cold and late springs with low temperatures, particularly at nights, and by not warm summers with a frequently overcast sky and rains. In spite of these conditions, the cultivation of maize as forage crop and even for grain in increasing, and the yield does not differ from those obtained in other parts of the country. Therefore, the cultivation of other stenothermic plant species, such as Sorghum, under the habitat conditions of the Szczecin Lowlands is possible, especially due to the significant progress in the farming and technology of the cultivation of this "new" species in Europe in recent years.

The purpose of the research is to assess the yielding potential of selected Sorghum and Sudan grass hybrids depending on the mineral nitrogen fertilizing in the climate and soil conditions of the Szczecin lowlands.

**Material and methods**. The field research[1] was carried out in 2011 at the Agricultural Experiment Station in Lipnik near Stargard Szczeciński (53°20'36.960"N, 14°58'130.908"E) on light sandy soil belonging to the rusty-brown soils. Soils in the study area are classified according to the Systematic of Polish Soils **[4]**. The soils in this region were formed mainly from glacial deposits and sediments deposited by glacial melt water. In the classification of agricultural suitability this soil belongs to the fifth complex (good rye soil suitability complex) and the gradation category IVb. The experiment was established with 12 varieties of Sorghum and Sorghum-Sudan grass hybrids. Sown were 5 varieties of Sorghum (*Sorghum bicolor* (L.) Moench): Goliath, Pluto, Rona 1, Sucrosorgo 506 and Super Sile 20 as well as 7 varieties of Sorghum and Sudan grass hybrids (*Sorghum bicolor* (L.) Moench × *S. sudanense* (Piper) Stapf), in the study referred to as Sudan grass: Freya, Green Grazer, Inka, Jumbo, Lussi, Mithril and Susu. These all varieties were cultivated with four levels of mineral nitrogen fertilizing (0, 50, 100 and 150 kg N per 1 ha). During the entire experiment they were uniformly fertilized with phosphorus and potassium ($P_2O_5$ and $K_2O$) to an extent determined based on the contents of available forms of both macro elements in the soil. The control object was KWS[2] energy maize (Zea mays L.) of the variety Atletico, FAO 280, sown at the correct time, optimal for maize (02.05.2011). The Sorghum and the Sudan grass, on the other hand, were sown on 19 May 2011, optimal for Sorghum – over two weeks later. These species were cultivated on plots of 1,5 × 12 m (harvest of 14,25 $m^2$) in rows, spaced at 35cm, in four replications. Towards the end of September the plants were harvested (Photo 1), the yield of fresh and dry mass determined for each plot and calculated into yield per 1ha.

[1] Research financed by the Ministry of Science and Higher Education in Poland out of the science funds in the years 2010-2013 as research project no. N N310 162938 (Productivity of sorghum and Sudan grass phytomass and its caloric value as well as the specific methane yield depending on mineral nitrogen fertilizing)
[2] KWS Polska Sp. z o.o. – Company that sells seeds of maize, sugar beet, rape, potato

*Photo 1. Harvest of Sorghum and Sudan grass with New Holland harvester (M. Bury)*

**Results**. The obtained biomass yield for all varieties of Sorghum and Sudan grass hybrids was high and amounted to maximum 86 Mg (1Mg = 1000 kg) of fresh mass per 1 ha (Table 1). The yield of the Sorghum and Sudan grass hybrid varieties (*Sorghum bicolor × S. sudanense*) varied between about 57 and 75 Mg of fresh mass depending on the level of nitrogen fertilizing (Photo 2). The Sorghum (*Sorghum bicolor*) yield was greater and ranged between 66 and 86 Mg of fresh mass per 1 ha, also depending on the rate of mineral nitrogen fertilizing. The fresh mass yield of both species was large, even on objects without nitrogen fertilizing (about 62 $Mg \cdot ha^{-1}$) and increased successively the higher the rate of mineral nitrogen fertilizing from 50 to 150 kg N per 1 ha within the range of from about 69 to about 80 Mg per 1 ha (Table 1). The fresh mass yield of the energy maize (Zea mays L.) of the cultivar Atletico (280), cultivated under the same soil and climate conditions and with a vegetation period longer by over 2 weeks, were lower than the Sorghum and Sudan grass yield, but not for all fertilizing variants. The average maize biomass yield amounted to about 63 $Mg \cdot ha^{-1}$ and varied between about 51 and 78,5 Mg per 1 ha, depending on the rate of mineral nitrogen fertilizing (Table. 1).

***Table 1. Fresh mass yield ($Mg \cdot ha^{-1}$)* of Sudan grass hybrids, Sorghum and Maize in 2011***

| Species | Mineral N fertilizing [$kgN \cdot ha^{-1}$] | | | | Average |
|---|---|---|---|---|---|
| | 0 | 50 | 100 | 150 | |
| Sorghum | 66,07 | 71,56 | 83,56 | 85,66 | 76,71 |
| Sudan grass hybrids | 57,10 | 65,97 | 69,92 | 75,13 | 67,03 |
| Average for Sorghum and Sudan grass | 61,58 | 68,76 | 76,74 | 80,39 | 71,87 |
| Maize | 51,13 | 52,93 | 67,67 | 78,50 | 62,56 |
| Average | 58,10 | 63,49 | 73,71 | 79,76 | 68,76 |

* 1Mg=1000kg

The biomass yields of Sorghum (*Sorghum bicolor*) and Sudan grass hybrids (*Sorghum bicolor × S. sudanense*) depended on the level of nitrogen fertilizing and





were on average 15 % higher than the fresh mass yield of the maize (Table 2). The yield of Sudan grass hybrids was higher in comparison with the fresh mass yield of the maize by average 12 % on objects without mineral nitrogen fertilizing and by 25 % on objects fertilized with the smallest dosage of nitrogen, i.e. 50 kg per 1 ha. With the increased dosage of nitrogen fertilizing of 100 kg N per 1 ha, the Sudan grass yield increased only by 3 % in comparison with the maize yield (Fig. 1), and was even lower by 4 % than the maize biomass yield on objects fertilized with the highest rate of mineral nitrogen (150 kg N per 1 ha).

*Photo 2. Sorghum and Sudan grass at beginning of September (M. Bury)*

The fresh mass yield of Sorghum (*Sorghum bicolor*), on the other hand, was on average 23 % higher than the maize yield and depended also on the applied dosage of mineral nitrogen fertilizing. The Sorghum biomass yield on controlled objects was about 29 % higher than the maize yield (Fig. 1, Table 2). With the increasing degree of mineral nitrogen fertilizing from 0 to 50 kg N per 1ha, the Sorghum yield grew by about 35 % in comparison with the maize yield. As the mineral nitrogen fertilizing increased, this difference lessened to 23 % for 100 kg N to 9 % for 150 kg N in favor of the Sorghum biomass (Table 2).

***Table 2. Fresh mass yield (%) of Sorghum and Sudan grass hybrids in comparison to Maize yield (Maize yield = 100)***

| Species | Mineral N fertilizing [$kgN \cdot ha^{-1}$] | | | | Average Maize = 100 |
|---|---|---|---|---|---|
| | 0 | 50 | 100 | 150 | |
| Maize | 100 | 100 | 100 | 100 | 100 |
| Sorghum | 129 | 135 | 123 | 109 | 123 |
| Sudan grass | 112 | 125 | 103 | 96 | 107 |
| Average for Sudan grass and Sorghum | 120 | 130 | 113 | 102 | 115 |

The biomass yield of both Sorghum species (Sudan grass hybrids as well as Sorghum) on objects without mineral nitrogen fertilizing (0 kg N per 1 ha) was on average 20 % higher than the fresh mass yield of maize. The most important difference to the maize biomass yield was obtained with the dosage of 50 kg N per 1 ha – where the yield was about 30 % higher. On objects where dosages of 100 and 150 kg N per 1 ha were applied, the average fresh mass yield of Sudan grass and sweet Sorghum was proportionately about 13 and 2 % higher than the maize yield (Table 2).

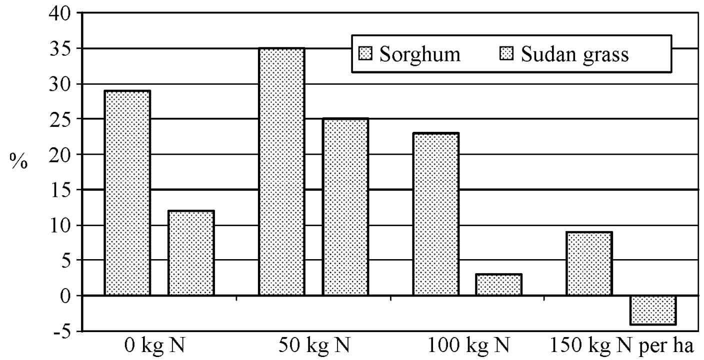


***Fig. 1. Increase of fresh mass yields (%) of Sorghum and Sudan grass hybrids in comparison to maize yield***

The results revealed the extremely positive influence of mineral nitrogen fertilizing on the fresh mass yield of maize as well as Sudan grass and Sorghum (Table 3). Regardless of the species and the amount of mineral fertilizing the biomass yield increased by about 18 % in comparison to the control object without fertilizing.

The first level of nitrogen fertilizing (50 kg N) increased the biomass productivity of all tested species in relation to the control object without nitrogen fertilizing (0 kg N per 1ha) by about 9 %. The strongest reaction to this dosage of mineral nitrogen fertilizing showed the variants of Sudan grass hybrids (about 16 %), and the weakest reaction the maize of the variety Atletico – about 4 % (Fig. 2).

With the increase of the dosage of mineral nitrogen fertilizing from 50 to 100 kg N per 1 ha the fresh mass yield increased further, by an average of another 18 %, regardless of the species. The greatest increase in the biomass yield was observed for the maize – of about 28 % (Fig. 2), and the smallest for the varieties of Sudan grass and Sorghum (of about 6 % for the Sudan grass and 18 % for the Sorghum).

The application of the highest dosage of nitrogen fertilizing (150 kg N) resulted in a significant increase of the fresh mass yield of all species of about 10 % in comparison with the dosage of 100 kg $N \cdot ha^{-1}$ (Table 3). The individual species reacted differently to the increased mineral nitrogen fertilizing: the maize of the variety Atletico reacted the strongest – the yield increased by about 22 %, the Sorghum less – the yield increased by about 10 %, and least of all the Sudan grass hybrid varieties, where the yield increased by about 6 % in comparison with the dosage of 100 kg $N \cdot ha^{-1}$ (Fig. 2).

In general, after the application of the dosage of 150 $kgN \cdot ha^{-1}$, the fresh mass yield of the tested Sudan grass and Sorghum varieties was about 31 % higher (Table 3) than the yield from the control object (0 kg N per 1ha).





***Table 3. Fresh mass yield (%) of Sorghum and Sudan grass hybrids in comparison to control object without fertilizing of nitrogen (0 kg N)***

| Species | Mineral N fertilizing [$kgN \cdot ha^{-1}$] | | | | Average $0\ kgN \cdot ha^{-1} = 100$ |
|---|---|---|---|---|---|
| | 0 | 50 | 100 | 150 | |
| Maize | 100 | 104 | 132 | 154 | 122 |
| Sorghum | 100 | 108 | 126 | 130 | 116 |
| Sudan grass | 100 | 116 | 122 | 132 | 117 |
| Average | 100 | 109 | 127 | 137 | 118 |

The dry matter yields were also depending on the rate of nitrogen fertilization and reach from about 19 to 21 Mg per hectare for Sorghum and Sudan grass cultivars (table 4) and from about 18 to 26 Mg per 1 ha for silage maize ("energy" cultivar Atletico, FAO 280).

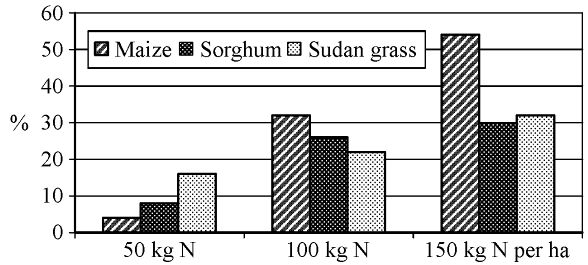


***Fig. 2. Increase of fresh mass yields (%) of Maize, Sorghum and Sudan grass hybrids in comparison to control without fertilizing of nitrogen (0 kg N)***

***Table 4. Dry mass yield (D.M.) and biogas and Methane yield per 1 ha***

| Specimens | Mineral N fertilizing [$kg\ N \cdot ha^{-1}$] | | Average |
|---|---|---|---|
| | 0 | 150 | |
| Sorghum | | | |
| Yield of D.M. [$Mg \cdot ha^{-1}$] | 19,67 | 21,23 | 20,76 |
| Biogas* [$Nm^3 \cdot ha^{-1}$] | 10798 | 11653 | 11412 |
| Methane* [$Nm^3 \cdot ha^{-1}$] | 6019 | 6495 | 6361 |
| Sudan grass | | | |
| Yield of D.M. [$Mg \cdot ha^{-1}$] | 19,36 | 20,45 | 20,38 |
| Biogas [$Nm^3 \cdot ha^{-1}$] | 8734 | 9227 | 9194 |
| Methane [$Nm^3 \cdot ha^{-1}$] | 4804 | 5075 | 5057 |
| Maize | | | |
| Yield of D.M. [$Mg \cdot ha^{-1}$] | 18,36 | 26,38 | 21,56 |
| Biogas [$Nm^3 \cdot ha^{-1}$] | 11772 | 16916 | 13822 |
| Methane [$Nm^3 \cdot ha^{-1}$] | 6470 | 9297 | 7597 |

1 $Nm^3$ – unit of mass for gases equal to the mass of 1 $m^3$ at a pressure of 1 atmosphere and at a standard temperature of 20 °C

The biogas and methane productivity of investigated crops calculated on literature base [5] was high (table 4). The biogas production per 1 ha oscillated from about 9000 cubic meters ($Nm^3$) for Sudan grass to 11000 cubic meters for forage Sorghum. The biogas production of energy maize was larger than of Sudan grass and Sorghum and reach in average up to 14000 $Nm^3$ per 1 ha (Table 4). The methane content was about 50 % of biogas yield. The results revealed the extremely positive influence of mineral nitrogen fertilizing on the methane yield of maize as well as Sudan grass and Sorghum (Table 4).

The last level of nitrogen fertilizing ($150 kgN \cdot ha^{-1}$) increased differently the methane productivity of all tested species in relation to the control object without nitrogen fertilizing (0 kg N per 1ha). The weakest reaction was observed of Sudan grass varieties by increasing of about 6 % and also – by Sorghum (increasing of 8 %). The strongest reaction to this dosage of mineral nitrogen fertilizing showed the energy maize, energy cultivar of KWS, Atletico (Table 4). The increasing of methane yields in comparison to object without nitrogen was very large, about 44 %.

**Conclusions**. The results of the experiment has shown that Sorghum (*Sorghum bicolor*) as well Sudan grass hybrids (*Sorghum bicolor* × *S. sudanense*) can be successfully cultivated in West Pomerania and can be complementary crops to silage maize (Zea mays L.) in the same soils- and climate conditions.

The obtained fresh mass yields for all varieties of Sorghum and Sudan grass hybrids were high and amounted from 61 to 80 Mg per 1 ha and dry matter yields ranged from 19 to 21 $Mg \cdot ha^{-1}$ depending on the level of nitrogen fertilizing. This has been reflected in the high biogas yields.

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***Бури М., Хури Г., Можджер Е., Кугляж К., Аморжи Б., Башуцька У.*** **Можливість вирощування та використання сорго й гібридів суданської трави (*Sorghum bicolor* (L.) Moench) як ресурсу для отримання біогазу у північно-західній Польщі**

Шляхом польового експерименту встановлено, що сорго двоколірне (*Sorghum bicolor*), а також гібриди суданської трави (*Sorghum bicolor* x *S. sudanense*) можна з успіхом вирощувати на легких піщаних ґрунтах Щецінської низовини, що дасть змогу збільшити групу рослин, які культивуються з метою отримання енергії, наприклад, при виробництві силосу для біогазової установки. Це було підтверджено високим врожаєм свіжої та сухої маси обох видів (сорго і суданської трави), досягнутим на сільськогосподарській дослідній станції Західно-Поморського технологічного університету в Щеціні у 2011 р., а також розраховано високий потенціал виходу біогазу та метану з одного гектара.

***Ключові слова:*** сорго, суданська трава, кукурудза, вихід біомаси, вихід біогазу і метану, Західна Померанія, північно-західна Польща.

***Буры М., Хуры Г., Можджер Е., Кугляж К., Аморжи Б., Башуцькая У.*** **Возможность выращивания и использования сорго и гибридов суданской травы (*Sorghum bicolor* (L.) Moench) как ресурса для получения биогаза в северно-западной Польше**

Путем полевого эксперимента доказано, что сорго двуцветное (*Sorghum bicolor*), а также гибриды суданской травы (*Sorghum bicolor* x *S. sudanense*) можно с успехом выращивать на легких песчаных почвах Щецинской низменности, что позволит увеличить группу растений, выращиваемых для энергетических целей, в частности, при производстве силоса для биогазовой установки. Это было подтверждено высоким урожаем свежей и сухой массы обоих видов (сорго и суданской травы), достигнутый на сельскохозяйственной опытной станции Западно-Поморского технологического университета в Щецине в 2011 г., а также рассчитано высокий потенциал выхода биогаза и метана с одного гектара.

***Ключевые слова:*** сорго, суданская трава, кукуруза, выход биомассы, выход биогаза и метана, Западная Померания, северо-западная Польша.





***УДК 631.15:658.27*** ***Аспір. Н.М. Борис[1] – НЛТУ України, м. Львів***

# УПРАВЛІННЯ ЕКОЛОГІЧНОЮ БЕЗПЕКОЮ ЕКСПОРТНОЇ ДІЯЛЬНОСТІ ПІДПРИЄМСТВ ЛІСОВОГО ГОСПОДАРСТВА ЗА УМОВ СТАЛОГО ПРИРОДОКОРИСТУВАННЯ

Обґрунтовано доцільність системного підходу до управління екологічною безпекою експортної діяльності підприємств лісового господарства. Визначено складові інтегрованого процесу управління за умов концепції сталого природокористування. Досліджено та класифіковано фактори впливу на екологічну безпеку діяльності лісових підприємств. Описано механізм управління нею відповідно до встановлених норм і вимог.

***Ключові слова:*** екологічна безпека, експортна діяльність, стале природокористування, системний підхід.

**Постановка проблеми**. Сучасна концепція сталого природокористування, на якій ґрунтується екологічний менеджмент передусім визначає циклічність процесу управління використанням природних ресурсів. Стосовно експортної діяльності така циклічність проявляється в тому, що виробниче навантаження на лісові ресурси компенсується заходами з відновлення лісів, а також заходами із захисту лісів від шкідливих наслідків, пов'язаних із виробництвом експортної продукції.

Сьогодні в багатьох дослідженнях, які стосуються проблем сталого (екологічного) природокористування, обґрунтовується, що екологічне управління природокористуванням, зокрема лісокористуванням, є системою технологічних, організаційно-економічних та інституціонально-регулювальних процесів, які інтегровані в загальний процес для досягнення балансу інтересів природи, суспільства й економіки. Критерієм такого балансу є екологічна безпека діяльності суб'єкта господарювання.

Управління формуванням екологічної безпеки експортної діяльності підприємств лісового господарства потребує застосування системного підходу, оскільки під управлінським впливом суб'єкта управління перебувають відносно самостійні, часто суперечливі процеси, які потрібно певним чином поєднати і взаємоузгодити. Тобто існує проблема між багатовекторністю процесів (контурів), які формують екологічне середовище експортної діяльності підприємств лісового господарства, і необхідністю інтеграції цих процесів у загальний про-

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