Final report

Novel Pathways of Biomass Production: Assessing the Potential of Sida hermaphrodita and Valuable Timer Trees (SidaTim)

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FACCE SURPLUS
SUSTAINABLE AND RESILIENT AGRICULTURE FOR FOOD AND NON-FOOD SYSTEMS

Kompetenzzentrum Niedersachsen • Netzwerk Nachwachsende Rohstoffe und Bioökonomie e.V. 3N

1. Evaluation of the development of *Sida hermaphrodita*

1.1 Task: Establishment of the pilot plant

Crop cultivation aspects of Sida were tested at the test site of the Lower Saxony Chamber of Agriculture in Werlte between 2016 and 2018. First, two different genotypes of *Sida hermaphrodita* (Sida North and Sida South) and *Silphium perfoliatum* (Cup-plant, one genotype) were compared. On the other hand, the establishment of the cultivation variants "seed" and "young plants" (seedlings) was examined. The test area was established between 23 May and 1 June 2016.

1.2 Experimentell setup

The experiments were designed as a block system with four repetitions. The individual plots each comprised ten rows of plants with a row spacing of 45 cm and a row length of 8 m (36 m² plot size). The sowing strength of the seed variants Sida and Silphium was 6 plants per m² (germination capacity 50%). The planting density of the seedlings was defined as 4 plants per m².

The six variants included the following combinations:

Variant 1: Sida seeds / Origin South

Variant 2: Sida planting stock / Origin South

Variant 3: Sida seeds / Origin North

Variant 4: Sida planting stock / Origin North

Variant 5: Silphium seeds / Origin Chrestensen, Erfurth

Variant 6: Silphium planting stock / Origin Chrestensen, Erfurth

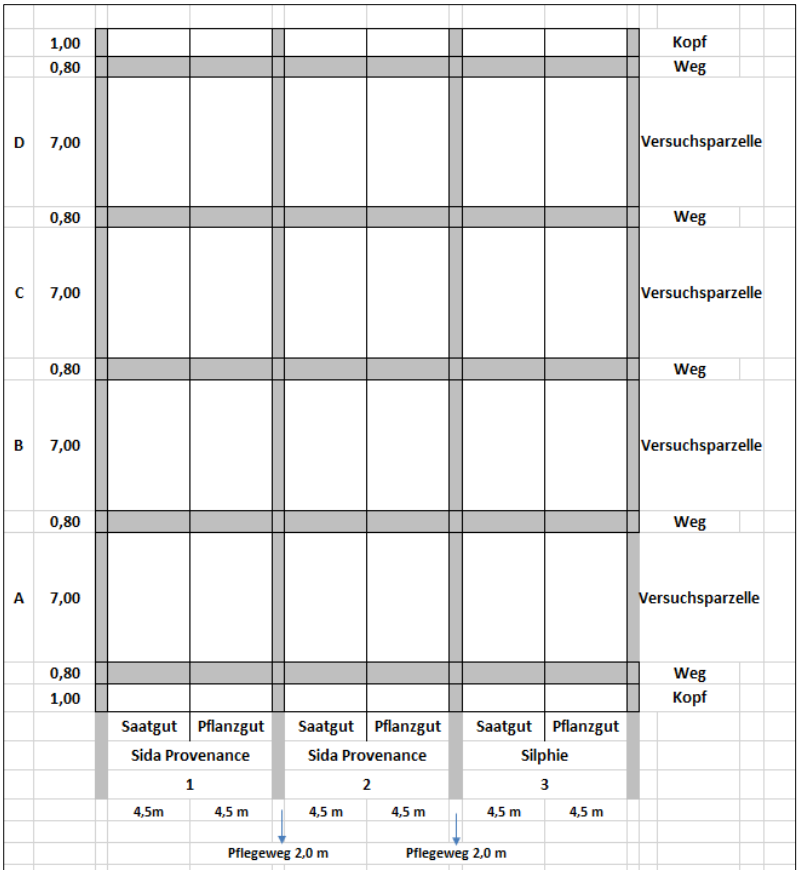
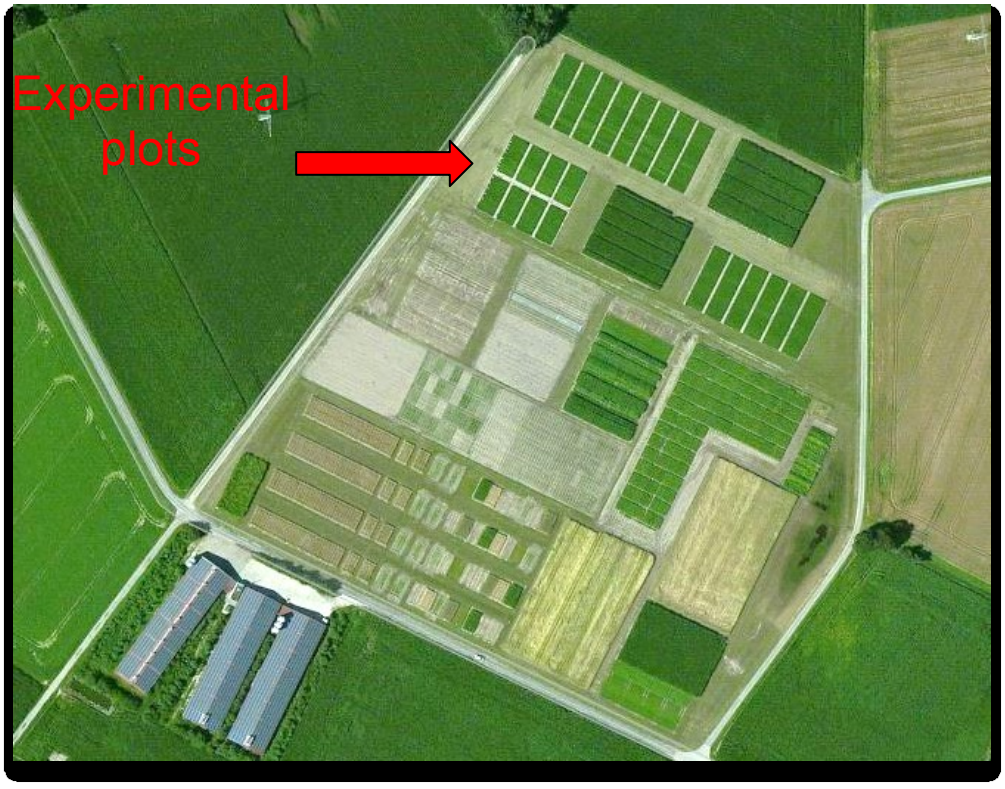


Figure 1: Overview of the Sida and Silphium plant at the test site of LWK Niedersachsen (Lower Saxony Chamber of Agriculture) in Werlte.



The crop development and the occurrence of diseases were recorded during vegetation. As part of the yield comparison, harvesting was carried out on three dates in the test years, with summer harvest (June), autumn harvest (Sept.) and winter harvest additionally for Sida (after the end of vegetation). In addition to a yield calculation, the energy yields at selected dates were analysed.

1.3 Collaboration with other bodies

The trials at Werlte are part of the overall project mentioned ab ove as well as the german test site for the joint project ERANET. Togehter with the polish, italian and british partner the trials were planned and performed. The evaluation of all the project sites is made in the joint final report, which is produced by the leadpartner the University of Freiburg. The test results described in the following are included in the final report. The current state of the scientific and technical knowledge also have been compiled together and are described in the final document of the EU project.

2 Evaluation

2.1 Development of established stocks

The experimental support of the Chamber of Agriculture of Lower Saxony included the preparation of the planting and sowing bed, fertilisation, sowing and planting, field emergence studies, replanting (transplanting from the side) of plants that had not risen or died, the isolation of plants in the seed variants and regular growth assessments, assessments for diseases and accompanying flora as well as the implementation of plant protection measures. The results are summarised below.

Experimental year 2016

Silphium crops developed to a well-developed rosette stage in the first year of stocking. Both Silphium variants reached growth heights of 10 to 15 cm at the assessment date in September. In comparison, the Sida variants showed a diverse development. The seed variant drilled in June reached the same stage of development (EC 19) as the Sida variant planted three weeks later. The planted Sida variant showed a clear developmental advantage, the plants of the southern origin reached plant heights between 1.57 m and 1.67 m. Also the further planted Sida variant 3 (origin north) established itself very well with a growth height of 1.35 m to 1. 55m.

Variant 1 (Sida South drilled) and variant 3 (Sida Origin North) both achieved considerably smaller growth heights of 0.81 m to 0.94 m (Sida South drilled) and 0.80 m to 1 m (Sida Origin North) thus also good establishment values.
In all Sida variants, botrytis-infested plants occurred, with variant 2 (Sida South planted) being most affected, followed by variant 4 (Sida North planted). In autumn 2016 (11.11.2016), the Sida variants (planted and seeded) showed a uniformly good degree of soil cover (6 of max. 9 rating points) and were free of associated weeds.

Experimental year 2017

The experiment was supplied with nutrients (80 kg N/ha; P, K, Mg after soil analysis) in March 2017 according to the fertilisation plan. The Sida variants showed a balanced crop on 04.04.2017. An exception was the planted variant Sida South, in which stronger plant losses were assessed. The missing parts were compensated by replanting.
Variant 2 (Sida South planted) showed an average of 8 shoots and an average plant height of 2.84 m on the assessment date at the beginning of July 2017 (summer harvest). The planted variant Sida North developed somewhat more heterogeneously and showed between 11 and 6 shoots. They reached a slightly lower growth height of 2.78 m on average. In comparison, the drilled variants were also able to achieve a similarly good crop development. The drilled variant 1 Sida South showed between 8 and 10 shoots, with a growth height of 2.59 m. The drilled variant Sida North showed a similar picture with 8 to 10 shoots and an average height of 2.49 m.

Figure 2: Sida Botrytis

On the assessment date in September 2017 Variant 4 (Sida North planted) reached the highest growth height with 2,74 m, followed by Variant 1 (Sida South drilled) with an average plant length of 2,69 m. The drilled Variant 3 (Sida North) reached a medium size of 2,47m and the Variant 2 (Sida South planted) had the lowest growth height with 2,29 m on average.
In comparison, the drilled Sida variants were about 20 cm lower in height than the reference stands (planted Variants).

Due to the warm and humid weather in June and July of 2017, the Sida plants displayed an incipient botrytis infestation. The condition assessment at the winter harvest showed only a very low conditional predisposition (2 to 3 of 9 points).

The year 2017 was characterised by above-average high and long periods of precipitation, while in 2018, an extreme summer drought at very high temperatures strongly influenced the development of all crops, including the tested permanent crops.

Experimental year 2018

The extreme drought and heat, which began on May 2018 and lasted until September, also affected the growth of Sida and Silphium, with the Sida South and Silphium variants showing good yields in the summer cut (July). From the summer harvest to the autumn harvest, only 97 litres of precipitation per square metre fell. Due to the massive drought, the experiment was harvested on 27.09.18. The average crop height was 3.12 m to 2.54 m when comparing Sida to the Silphium. When comparing the Sida variants, it was noticeable that the drilled Sida North variant only achieved an average height of 2.94 m. The other 3 variants reached an average height of 3.19 m.

In comparison to other agricultural crops, e.g. corn, the Sida Variants as well as Silphie proved to be drought resistend.

During the evaluation of fungal diseases, it was found that on average, five plants per variant were infected with botrytis across all Sida variants. It was noted that the planted Sida variants were slightly more infested than the two drilled variants. Further assessments before the harvest showed a relatively even crop. Low conditional predisposition was determined. The conditions could only be determined in the repetition of the drilled variant Sida North. According to BSA, this repetition was given a score of 5.

2.2 Presentation of crop yields

After the establishment year 2016 of the permanent crop stocks, the yield development was determined on two or three harvest dates in 2017 and 2018.

The following figure shows the Sida crop yields of the seed origins South and North and the two cultivation variants Seed and Young Plants at the experimental site in Werlte in comparison to Silphium. The first and second harvest years are shown.

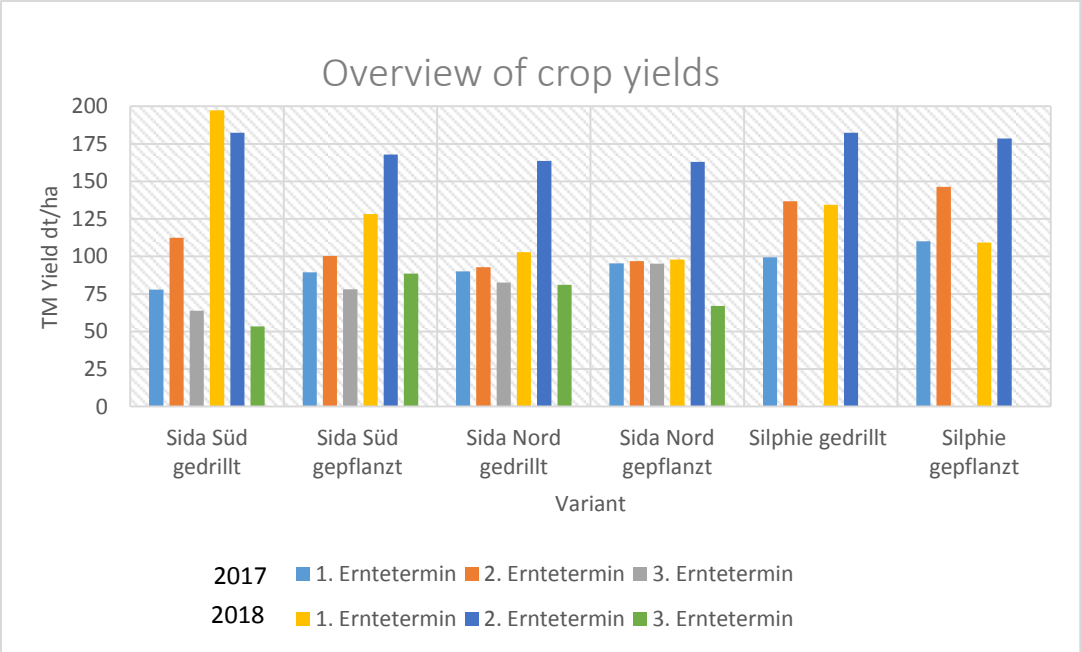


Figure 3 Overview of crop yields from 2017 and 2018 in TM Yield dt/ha

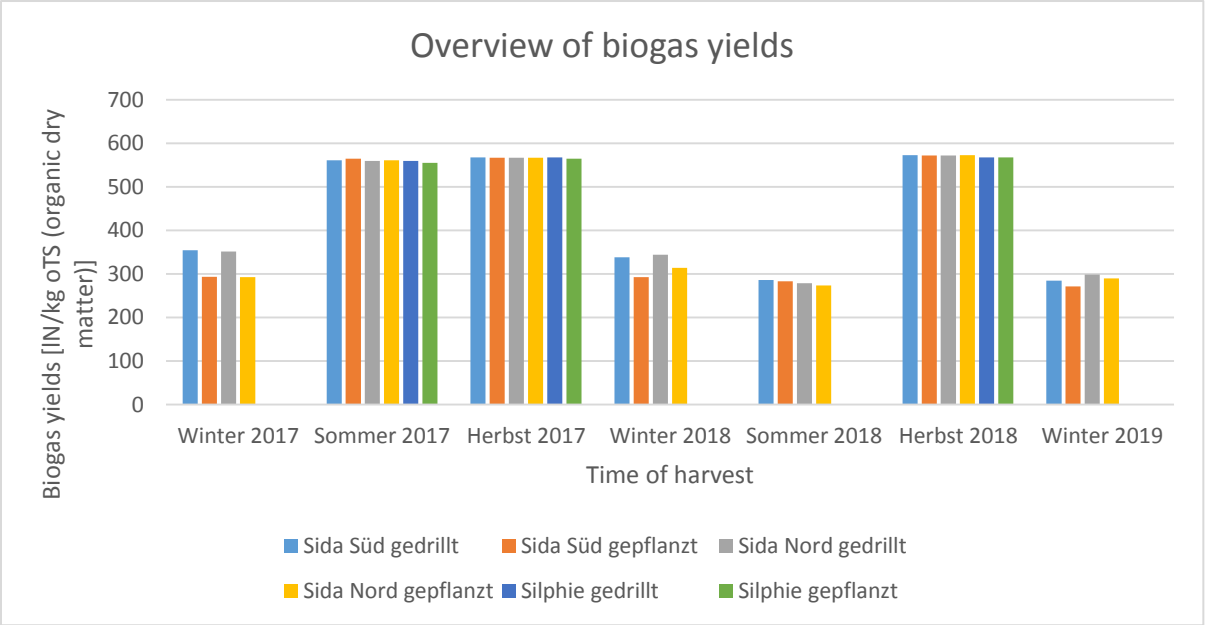
With a very early harvest (harvest date July), Sida achieved impressive yields of 93.7 dt/ha in 2017. In 2018 the summer harvest showed an average of 128.3 dt/ha. The main yield of the Sida crops was always achieved at the September harvest date, which is relevant for biogas utilisation. In 2017, the average yield of all Sida variants from the autumn harvest was 114.2 dt/ha and in 2018 172.9 dt/ha. The simultaneously harvested Silphium recorded a slight yield advantage in both years (2017: 146.2 dt/ha and 2018: 180.5 dt/ha).

A comparison of the Sida origins showed differences in the yield performance. In September 2017, the Sida South variant recorded around 4 dt/ha higher yields than the Sida North seed variety in the second harvest. In the following year, the yield advantage of the southern variety increased to 12 dt/ha higher yields than the North Variants.

In comparison to the young plant nursery, the drilled plots showed stable yield performances and reached an additional yield of around 4 dt/ha by the second harvest date in September 2017, which was further increased to 8 dt/ha in 2018. This shows that well-established drilled crops achieve a yield comparable to that of young plants.

2.3 Biogas yields

The following figure shows the biogas yields of the Sida variants at the test site in Werlte in comparison to Silphium. The biogas yields of the different harvest times were determined partly theoretically and partly by biogas batch tests.



Picture 4Overview of biogas yields at the various harvest times in lN/kg oTS

The biogas yields for summer 2017 and autumn 2017 and 2018 were investigated by LUFA Nordwest. The determination was made with the help of the theoretical gas yield according to Baserga. However, since no digestibility is available in this context, the gas yield for the material under investigation cannot be given reliably, and a reduction in the realistic gas yield of up to 50 % is possible.

The calculated biogas yield values show a uniform picture of the different variants. A comparison of the 2017 and 2018 harvests shows an average value of 570 lN/kg oTS for all Sida variants. Also the theoretically determined biogas yields for Silphium are on a comparable level and show no noticeable difference.

To substantiate the results, biogas batch tests were carried out at the University of Applied Sciences and Arts (HAWK) in Göttingen. The gas yield potential was determined in accordance with VDI Guideline 4630. The biogas value determined by the batch tests differed in correlation to the stage of development of the plants between 281 lN/kg oTS (summer harvest 2018) and 310 lN/kg oTS (winter harvest both years). At the end of vegetation, there are slight differences between the planted and drilled variants, but these are not statistically significant.

2.4 Calorific value

As an alternative form of use, Sida is suitable as a solid fuel. The respective winter harvest (February) was analysed to determine the calorific value during the trial. At the time of the

winter harvest, the harvested material consisted only of dry stalks and very little dry leaf material. The average ash content was 3.5%, well below that of straw (8.7%).

The calorific values of the two *Sida hermaphrodita* origins North and South are comparable and ranked between 16.41 MJ/kg TS (dry mass) and 17.75 MJ/kg TS. The highest values were achieved in the third year of cultivation. In addition, a small, continuous increase in the calorific value can be observed over the three years of cultivation for Sida South. No significant effect of the cultivation variants (drilled/planted) on the calorific value is apparent.

The calorific value of the Sida variants are comparable to short rotation plantations (SRP), which calorific value shows an average between 17-19 MJ/kg TS (KTBL, ATB, FNR (2006): Data collection EP, leaflet poplar trees, willow).

The results of the calorific value in relation to the dry matter are presented in the table below for the experimental period.

	Year	**Cultivated variant**		**Mean**
		drilled	**planted**	
Sida North	2017	17.31	16.98	17.14
	2018	16.41	16.68	16.54
	2019	17.57	17.75	17.66
	Mean	**17.09**	**17.13**	**17.11**
Sida South	2017	16.41	16.94	16.67
	2018	16.76	16.99	16.87
	2019	17.32	17.61	17.46
	Mean	**16.83**	**17.18**	**17.00**

Table 1: Results calorific value [MJ/kg TS]

3. Accompanying ecological research

As part of the SIDATIM project, extensive accompanying ecological research was carried out together with the University of Hanover, and an invasiveness test was carried out in the second year of testing.

In the months of July, August and September 2018, various experimental investigations were carried out on 12 days with the aim of answering the following questions:

1. Do the cultivated areas of Sida hermaphrodita contribute to the conservation of biodiversity? (Corresponds to milestone M5.9, see appendix)
2. What is the invasive potential of Sida hermaphrodita? (Corresponds to milestone M5.10, see appendix)

The experimental investigations took place on three cultivated areas in the districts of Osnabrück (Bramsche, planting 2017), Vechta (Neuenkirchen-Vörden, planting 2014) and Emsland (Werlte, planting 2016) in Lower Saxony. In order to clarify whether the cultivated areas of Sida contribute to the conservation of biological diversity, it was investigated whether Sida could be of interest to flower-visiting insects and whether the accompanying flora contains site-specific or endangered or protected species. In order to assess the invasive potential, the distribution density and the maximum propagation distance of Sida sprouts in the adjacent vegetation of the cultivated areas were recorded, and it was determined over which diasporas the propagation takes place.
It can be noted that Sida hermaphrodita is able to spread from the cultivated areas vegetatively and generatively. In addition, contrary to scientific literature, it has been shown that the seeds are capable of germination and growth even if they are mown regularly. However, it must be determined in further investigations whether the plant has the ability to establish itself. Sida probably serves as a potential food source for frequent flower-visiting insects in landscapes with cleared vegetation. It is probably uninteresting for endangered wild bee species. As the sampling was carried out at only three sites, further investigations need to be carried out in other climatic regions.

The detailed report on the analysis and assessment of biodiversity or biological diversity and on the assessment of the invasive potential of *Sida hermaphrodita* in the SIDATIM project is attached as an annexe.

4. Interviews

Two countries, Poland and Germany were selected for the study, as it was known to project partners from these countries, that some farmers were already growing Sida and Silphium there. In Germany, farmers were interviewed via face-to-face and telephone interviews. The interviews lasted between one and one and a half hours. The database maintained by the "Sida working group" served as a basis for the selection of growers, and further growers known to the project partners were contacted.

Germany

Germany covers an area of approximately 357,021 km^2. The average farm area in Germany is substantially larger than in Poland, at 87.7 hectares. However, this marked very large differences in farm size between the different regionso of Germany, with farm sizes ranging

from an average of just 3.5 hectares in Hamburg to over 400 hectares in Brandenburg, Mecklenburg-Vorpommern, and Sachsen-Anhalt.

Table 1. Showing selected statistical data for agricultural holdings in different regions of Germany in 2016 (Source: FADN)

Country	Region	Total Utilised Agricultural Area	Cereals	Other field crops	Forage crops
Germany	Schleswig-Holstein	97.3	32.0	10.4	53.2
	Hamburg	3.5	0.0	0.0	0.1
	Niedersachsen	80.8	29.3	10.6	38.5
	Nordrhein-Westfalen	57.6	23.9	6.1	25.6
	Hessen	76.8	31.0	9.7	33.6
	Rheinland-Pfalz	55.6	20.2	7.4	20.3
	Baden-Wüttemberg	51.7	20.0	4.1	24.4
	Bayern	48.9	17.7	4.9	25.2
	Saarland	113.4	35.1	8.3	67.5
	Brandenburg	442.8	187.2	61.3	177.2
	Mecklenburg-Vorpommern	445.3	199.3	102.1	132.7
	Sachsen	298.8	131.5	60.6	100.1
	Sachsen-Anhalt	425.0	204.4	95.0	115.8
	Thüringen	435.8	198.0	92.5	136.3
	Average for Germany	87.6	35.0	12.5	37.2

Distribution of Sida production

41 companies were surveyed. These farms surveyed were distributed unevenly across Germany. From this distribution, it was possible to identify six "main cultivation areas" in Germany including Lower Saxony (five farms), North Rhine-Westphalia (five farms), Brandenburg (five farms), Saxony (seven farms) and Bavaria and Baden-Württemberg (five farms), each with more than five farms involved in growing Sida.

Figure 1. Map showing regions of Germany where at least five or more producers of Sida were identified

The majority of the farms surveyed had a farm size of 1-5 ha (27 farms). 13 farms were larger than 5 ha, a maximum of 15 ha and 1 farm was larger than 15 ha.

Clearly, this is a very approximate suggestion of the distribution of Sida in Germany since it only includes farmers who were registered with the Sida working group (AK-SIDA) or who were known personally by the research team at 3N Kompetenzzentrum. However, an accurate description of the distribution is impossible to make currently because historically, there has been no requirement to register Sida enterprises in Germany. However, since 2018, Sida has been given a crop code (804) within the agricultural support framework. This should allow clearer statements to be made in future concerning the area of Sida cultivation, although it is also worth noting that not all farms apply for agricultural subsidies.

Uses of Sida

All of the respondents surveyed had some experience in the growth and use Sida. 24 of the respondents were professional farmers or gardeners and about 12 of the farmers were part-time farmers. 2 companies worked in the propagation and breeding of seeds and seedlings.

4 state and university agricultural research institutes were also surveyed. All were generally positive about their experience in the cultivation and use of Sida.

35 farmers had their own heating plant or plan to build one in the future. 34 farmers used Sida chips for combustion in their own stoves, which were mainly mixed with wood chips. For this particular application, farmers stated that the Sida chips accounted for between 20 and

50% of the total volume of material used. None of the respondents had identified any problems with the use of Sida chips for energy production.
However, only 4 of farmers had any experience in using Sida for biogas production. And at the time of the survey, none of them was using the bi-annual harvesting approach proposed for biogas production.
Of some surprise was the finding that two farmers said that they had provided Sida as roughage to livestock farms in the neighbourhood in the summer of 2018 due to a lack of fodder caused by the long and persistent drought.
One company also mentioned that it was using both Sida and Silphium for biomining. The company was currently investigating how to reduce chlorinated hydrocarbon contaminated soils at former Russian military airports in eastern Germany. In total, this covered an area of approximately 500 hectares.

Constraints to Sida production

Farmers stated that planting, sowing, growing and maintaining Sida could pose challenges. For example, all the farmers interviewed (100%) stated that weed control, especially in the first two years of plant establishment was a problem.

34 farmers also made it clear that the lack of technical knowledge on Sida was a key limiting factor. In particular, they stated that lack of or limited knowledge of seed treatment techniques, planting techniques (20 farmers), and harvesting techniques had been challenging. High initial investment costs, long capital commitments, and low profitability were all considered to be factors that led to considerable difficulty in establishing and using Sida.

Currently, 4.8 hectares of land is cultivated on eligible land in Lower Saxony in the districts of Lüneburg, Vechta and Osnabrück. To the best of our knowledge, however, we believe that the area under cultivation in Lower Saxony is likely to be about 15 hectares as not all areas of Lower Saxony are covered by agricultural subsidies. The possible lack of eligibility of Sida for agricultural subsidies is likely to act as a barrier to uptake of Sida cultivation, both within Germany and in other EU states, which have not introduced a code 804 for Sida into their agricultural support frameworks.
Generally, farmers stated that they thought there would be a more important role for Sida in the future, given its potential uses as a fuel, raw material, and animal feed. The majority of

Sida growers (30 growers) felt that there could be a small, future expansion of Sida cultivation on their own land.

However, although 37 farmers said they would continue to grow Sida on their agricultural land, they said this would tend to be on small fields, in unfavourable locations and with low to medium site and soil quality. The farmers themselves noted that this would not necessarily result in high yields.

Markets for Sida and Silphium

A number of further measures and conditions were identified as necessary by this survey. These included:

- A commitment government and administration for alternative energy sources
- long-term contracts for the cultivation of energy crops and the supply of biomass
- The creation of effective biomass markets operating according to the laws of supply and demand
- Biomass storage facilities
- Popularization and improvement of biomass production for energy production
- Logistics and supply chain development for biomass for energy production,

The survey carried out as part of this project has confirmed the need for these measures.