Nachhaltige Kompostverwertung in der Landwirtschaft

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Translation German to English of the summary of the report "Nachhaltige Kompostverwertung in der Landwirtschaft" (Sustainable Agricultural Compost Utilization) 2003

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A. Summary

The agricultural application of suitable quality guaranteed composts, which is economically desirable for the recycling of resources (organic matter, nutrients), has yet to reach the potential objectives. Possible reasons are insufficient knowledge about the longer-term effects of compost on the soil fertility, the influence on the quality of the harvest products as well as possible ecological risks (ground water). Furthermore, little is known about the economic benefits of compost applications as well as suitable marketing strategies.

This situation was the starting point for the research project of the Deutschen Bundesstiftung Umwelt (DBU) research group. With the main focus on "Biowaste recycling", it was conducted between 2000 –2002. The main aim was to reach more utilisation security for farmers and also to clear widespread reservations. The main aims were as follows:

- To clear unanswered questions of the sustainable utilisation of quality guaranteed composts and to compile or to specify guidelines for the practical application and the concrete conditions for the use in agriculture.
- To work out the economic advantages of compost applications and its ecological assessment.
- To generate marketing strategies, which correspond to the practical requirements of the agriculture and
- To propagate broadly in public the compiled project results by suitable forms to improve, in the medium term, the acceptance for compost utilisation in agriculture.

A1. Sustainable compost utilisation – agronomic advantageous effects and possible risks

The purpose of this part of the project (the following projects are based on those results) was, to estimate as practically relevant and as realistically as possible the positive effects and possible risks of the agricultural compost utilisation, to define in a more comprehensive way the conditions for a sustainable and in the long term environment friendly compost utilisation. Six long term compost endurance tests were carried out and used to represent the nationwide soil and climate conditions for agricultural plant cultivation. Additional comprehensive overview investigations were evaluated, to estimate the current situation for more considered compost ingredients.

The methodical concept of the long term compost tests guarantees suitability of good practice suitability and practice transferability of the project results found, due to the following reasons:

- Arrangement mainly on medium and heavy soils, on which a compost effect is to be more likely.
- Examination of graded compost supplies (yearly 5, 10 or 20 t / ha DM (tonnes per hectare dry matter) in combination with graded supplement N-fertilisation (50 or 100% of the optimum fertilisation), to check the optimum amount of compost supply and to work out the amount of the necessary supplementary N-fertilisation.
- Choice of a typical crop rotation with medium to high nutrient uptake (“corn” or. “silo corn”/ winter wheat/ winter barley), which are representative for numerous

farmers nationwide. The uniform crop rotation on all test locations allows a good comparability of the locations.

- Complete demonstration on agricultural fields of full time farmers, exclusive supply of quality guaranteed composts, set up of so-called "tandem teams" (farmer and compost facility) and their active inclusion in the demonstration test– these are all conditions for a very practically oriented project treatment.
- Relatively long test duration of 5 (two locations) or 8 (four locations) years: good conditions to reach a sustainable, i.e. long-term compost application.

Building up on this wide and academically based project, all important advantageous impacts and possible risks of agricultural compost applications were evaluated and valued according to a comprehensive long term project set up.

A 1.1. Agronomic advantageous effects

The **results of the agronomic evaluation** document, that the advantages of the agricultural compost applications (advantage effects) are always the sum of single effects, which are reflected in the yield as well as in raised soil fertility in the end. Compost effects develop - as opposed to effects of the mineral fertilisers – in general more slowly and are measurable mostly only after several years. Therefore, for sustainable fertilisation and soil improvement regular compost supplies over longer time periods (3 - 10 years) are imperative.

Significant additions of resources and nutrients are added with agronomic maintainable compost applications of 6 - 7 t / ha or 20 t / ha every three years (Table 1). First, there is a supply in organic matter, which has a clearly positive influence on the humus balance. This is beside the significance for the fertilisation (nitrogen) - also the requirement for different "soil-improving" effects. By the supply of lime in the scale of preservation fertilisation, the pH value of the soil can be stabilised or in the favourable case step by step raised in a step by step way. Therefore for the fertilisation, there are **considerable saving potentials** supplies of both substance suppliers.

Of all the nutrients phosphorus and potassium are the most important for the fertilisation effect. Both nutrients have a very rapid fertilisation effect. The experiments clearly increased "plant-available" concentrations in the soil, thereby an improved maintenance situation in the resulted soil. Due to their high fertiliser efficiency and in the interest of a well-balanced nutrient balance, they have to be taken into account for the fertiliser balance, i.e. they can completely substitute the base fertilisation (a potential for cost reduction). Due to this, at the same time those supplies become the limiting factor for the compost application rates.

Table 1. The project summary results for advantageous effects of agricultural compost utilisation for fertilisation and soil fertility.

Valid for horticultural optimum compost supplies of 6 - 7 t / ha of DM yearly or 20 t / ha DM every three years.

Supplies with resources and nutrients		
Resource	**median range**	**Conclusion**
Organic matter t / ha DM	2.5 - 3.0	clearly positive for humus balance
Lime - CaO t/ha	2.0 - 3.0	positive for lime balance
Nutrients kg / ha	**median range**	**Nutrient balance on average**
Nitrogen - N	90 - 130	well-balanced to slightly positive
Phosphorus - P_2O_5	50 - 70	well-balanced
Potassium - K_2O	70 - 110	uptake medium: positive uptake high: weakly negative to well-balanced
Magnesium - MgO	50 - 75	very positive

Soil effects: humus, lime and nutrient supply		
Parameter	**changes in 5 - 8 years time**	**Conclusion**
Humus content	Increase around 0.2 - 0.5%, average increase rate of 0.1% per 8 t of additional organic matter	Balance of the organic matter unambiguously ensured
N_t content	Increase around 0.01 – 0.02%, average increase rate 0.01% per 500 kg N_t addition	Low rise of N_t pool
pH	pH preservation or in the most favourable case increase around 0.2 - 0.4 units	Maintenance lime addition

Fertilisation efficient nutrient contents	**Chargeable proportion [%] of total supply**	**Efficiency of fertilisation and chargeable for fertilisation balance**
Nitrogen short term (1 - 3 years) medium term (4 - 8 y.) medium term + raised Nmin content	 0 – 3 5 – 8 10 - 15	 Low fertilisation efficiency short-term increase max. 5% medium-term increase max. 10%, without Nmin content
Phosphorus medium uptake crop types uptake-strong crops	 35 – 45 50 - 60	high fertiliser efficiency full charging, thereby normally the limiting factor of compost addition
Potassium medium uptake crop types high uptake-strong crops	 30 – 40 50 - 60	
Magnesium medium crop types	5 - 10	low fertiliser efficiency long-term supply

The high Mg supply with compost that lead to a considerable positive balance and with only low fertiliser efficiency, is of no disadvantage. This **reduces** the permanent Mg leaching of the soil and involves no dangers for plants (**phytotoxicity**) as well as for the ground water due to only moderate solubility.

Table 1 Summarised project results for agricultural advantages of compost utilisation for fertilisation and soil fertility (continuation).

Effects on the soil: "soil improvement"		
Parameter	**Trend**	**Consequences for application**
Soil structure		
aggregate stability	clear	ground more elastic and mechanically more loadable, protection against soil compactions, decrease of erosion
Lower compaction	available	Increased aeration and drainage
Water balance		
Pore volumes and distribution	available	increase of middle pores and coarse pores, better aeration
Available field capacity	clear	improved gas exchange, raised water storage capacity, raised water storage during dryness, increased protection of the plants against moisture stress
Water content	clear	
Water capacity	clear	
Water infiltration	uncertain	better water transmissibility with strong precipitation, prevention of water logging (Staunässe)
Soil microbiology		
Microbial biomass	clear	Activation of the soil biota, increase of the robustness against harmful organisms and also against physical ground loading, improved mineralisation of organic substance, improved soil fertility in general
Dehydrogenates activity	clear	
N mineralisation	available	

Beside the supply in **phosphorus** and potassium the N_t supply can become the limiting factor for the compost supply. To avoid a high incalculable N_t pool in the soil, the N_t supply with compost has to be limited to 170 kg / ha yearly. Special care requires the proper supply of the mineralized N fraction for the additional mineral N-fertilisation, to avoid high soluble N-fraction levels in the soil:

After short-term compost application (1 - 3 years) this fraction (mineralised fraction) is still negligibly low with max. 5 %. Nevertheless, for precautionary purposes the mineral N fertilisation has to be reduced medium-term on average of 10 %, including for raised N_{min} fraction in the soil, the reduction has to be around 15 %. Modifications depending on the kind of compost are possible between 0 (green waste composts) to 25% (biocomposts rich in N).

The test results show (Table 1 Continuation), that the massive supply of organic matter with compost leads to perceptibly positive influence on all the essential **"soil improvements" as soil-physical and biological parameters** like the soil structure, water balance and especially the soil microbiology. Those effects considerably cause

gradual soil fertility advancement. They mainly improve the essential qualities as traffic ability of the ground, erosion, water storage and soil biological activity to use as growing.

The sum of all advantageous effects of agricultural compost applications is reflected best of all in the yield of the crop. On average, after several years' tests there are indications, that intensive crop production conditions (removal of all harvest products including straw), is more and more usual in regions with high agriculture production (e.g., southwest Baden Wurttemberg, Köln-Aachen Bucht) may provide an additional profit of 5 - 8%. For lower production intensity such clear profit effects of the compost application are rarer.

In the medium and long term those "soil-improving" effects of regular compost applications have at least the same, if not even a bigger significance as regards fertilisation effects. In their sum - this point the experiences from 5 or 8 years compost long term tests - both groups of advantage effects qualify composts, under suitable location terms and terms of utilisation, as valuable secondary raw materials (organic NPK fertiliser) for sustainable application in plant production.

A 1.2. Possible risks

The results of the comprehensive **assessment of possible risks** point, that the agricultural compost utilisation in total only shows low risks, that are controllable and tolerable if the rules of “good technical practice“ are kept. Terms for this fact are that:

- If possible quality guaranteed composts should be used, with low heavy metal contents and that satisfy further requirements and
- Horticultural tolerable add-ons of yearly 6 - 7 t / ha DM (20 t / ha DM every three years) are not exceeded.

For all the possible risks, in so far they are even relevant, **the heavy metal situation** ranks first. The current heavy metal concentrations for composts are on average clearly below the limiting values of the “Bioabfall-VO” (Table 2). Only for Cu and Zn higher rates are recorded, but still below the limiting values. Although the heavy metal supplies with regular compost applications are very low. Nevertheless, a perceptible positive balance always remains in the soil, because the plant uptake are only less than 10% (Pb, Cd, Cr, Ni) or in the more favourable case (Hg, Cu, Zn) up to 30% of the supply amount.

So for regular compost application, a gradual increase of the heavy metal contents in the soil, with priority for Cu and Zn can’t be excluded. Nevertheless, an objective risk analysis has shown that this risk is controllable and calculable. The accumulation in soil runs very slowly. Only after 10 to 20 years (for Ni and Hg 30 to 40 years) a minimal increase is analytically even noticeable. Dangers for irreversible, damaging soil contaminations don’t exist in the medium term.

Table 2. Summary of project results for possible risks of agricultural compost application.

Valid for horticultural optimal compost supply of **6 - 7 t / ha DM yearly** or **20 t / ha DM every three years.**

Parameter/ criteria	Results	Evaluation
Heavy metals		
Composts	**Median range**	**Evaluation**
Contents[1] in % of limit value [2]		
Hg	10 - 20	Low exhaustion of the limit values
Pb, Cd, Cr, Ni	25 – 35	
Cu, Zn	45 – 55	higher exhaustions of the limit values
Denial in % of the supply		
Pb, Cr, Ni, Cd	1 – 10	Balance always clearly positive, however supplies in total very low
Hg, Cu, Zn	10 – 30	
Soil contents	**Change in 5 to 8 years**	**Evaluation**
Total content	Unchanged	low increases measurable only in the long term (10 - 50 years) in the medium term no danger of soil contamination
Mobile contents		
Pb, Cr	Consistently	no danger of doubtful mobilisations
Cd, Ni, Zn	Downward	
Cu	Slightly upward	
Plant contents	**Change in 5 to 8 years**	**Evaluation**
Total content	Unchanged	minimum increases with Cu possible Reduction in quality of the harvest products not proven
Organic pollutants		
Composts and soil	**Median range**	**Evaluation**
Compost contents[3] in % of orientation values [4]		
PCB	20 – 30	very low, close to background load
PCDD/FA	35 – 50	
Soil content	Without influence	in the area of the background load

Legend:
1. Overview investigation Germany of 2000 and 2001: 6,500 samples
2. Limiting values contents BioAbfV for compost applications of 20 t / ha DM all three years
3. Random compost checks of the compost long term tests
4. Orientation values according to composting decree (Kompostierungserlass) Baden-Wurttemberg 1994

Table 2 Summary project results for possible risks of agricultural compost application (continuation).

Parameter/ criteria	Results	Evaluation
Further possible risks		
N-excess of the compost supply	**Median range**	**Evaluation**
Increase of N_{min} content in kg/ ha	5 – 10	• no quick, ecologically doubtful rise of the dissolvable N pool in the soil • N leaching controllable
N leaching out of the soil	Minimal	
Foreign matters and stones[5]	**Median range**	**Evaluation**
Foreign matters > 2 mm: content in % of DM	0.02 - 0.05	• clearly lower than limit values • quality guaranteed composts practically free from foreign matters, stone content low
Stones > 5 mm: content in % of DM	1.0 - 1.5	
Phyto hygiene	**Evaluation**	
Plant pathogen	with high temperature composting not present	
Epidemic hygiene	**Evaluation**	
Human pathogens (Salmonella)	with high temperature composting not present, no risks for the hygienic quality of the harvest products	
Weed seeds and weed trimming	**Evaluation**	
Weed seeds composts [5]	with high temperature composting practically not present	
Weed trimming field surface	in tests (42 Boniturjahre!) completely no raised weed trimming compared to control (without compost)	

Legend:
5. Limiting values BioAbfV

The Cu and Zn supplies are, as both heavy metals are essential trace nutrients for plants and urgently needed for their nutrition, not only a disadvantage. These - absolutely low – supplies are, on the contrary, on soils with low concentrations of those trace nutrients even desired, because they are important for a sufficient nutrition of the plants (regular fertiliser supply of these trace nutrients are 5 - 10 times higher). As long as geological background values as well as the limiting soil values in accordance with the Bioabfalll-VO (Biowaste Ordiance) are clearly below the limit, the Cu and Zn supplies of the compost applications are tolerable anyway.

Nevertheless, permanent attention and efforts are required, to guarantee a precautionary and sustainable soil protection, to make sure that the heavy metal status in the soil does not change negatively by compost applications. For this purpose the heavy metal supply with compost applications has to be lowered as far as possible ("minimisation order"). In addition, compost should be only used for soils, that fall clearly below the background values of “Bundes-Bodenschutz-VO” (Federal Soil Protection Ordinance). Further the heavy metal situation is getting additionally relaxed by the fact, that no raised heavy metal mobility was ascertained in the tests - the mobile contents of Cd, Ni and Zn even

decrease using compost - and also the heavy metal concentration in the harvest products remained unaffected.

The persistent **organic contaminants** are proved to be no risk for the compost application. The contents of polychlorinated biphenyls (PCB) as well as polychlorinated dioxins/ furans (PCDD/F) for random check investigations range completely in very low concentration areas near the background contamination. In the soils of the test locations also no change of the ubiquitous contents were recorded.

Numerous investigations attest, that the **N-mineralisation** of the organic matter added to the soil with compost takes place relatively slowly and so controllably. The N_{min} (N_{min} = mineral nitrogen) contents rose in comparison to the control without compost on average by 5 – 10 kg / ha. Against frequent supposition a sudden, ecologically doubtful rise of the dissolvable N pool in the soil is not to be feared. Also the possible N leaching to the ground water is controllable by using suitable measures (consideration of the N_{min} contents for the N-fertilisation balance, catch crop cultivation and decreased compost supply).

Numerous investigations within the compost quality guarantee for RAL-GZ 251 showed, that the **epidemic and phyto hygiene** of the used composts is always guaranteed. A proper high temperature rotting ("Heissrotte") (at least 65 °C for a period of 7 days) has occurred. The same is the case for **germinal seeds and plant parts capable of growth**. Extensive overview investigations (Table 2) proved that composts are practically free of them. Compost long term tests for 42 (!) "Boniturjahre" proved that also the pest plant populations in agricultural crop land did not raise using compost. By this fact the often proposed fear of increased pest plant populations after compost applications is disproved and this issue can be evaluated as not true.

The **foreign matters > 2 mm and stones > 5 mm** of the composts fell clearly below the limit values of the Bioabfall-VO. Today, high-quality composts contain only low foreign matter contents of less than 0.05% DM, i.e. they are practically free of it. Nevertheless, for the farmers compost acceptance it is indispensable, that composts are free of foreign matters, above all, free of plastic foils, as they can greatly interfere with the visual appearance after the compost application, although no danger for soil and harvest products exist. Nowadays, the stone contents reach on average 1.0-1.5% DM and are for this reason, no problem for the utilisation.

A 1.3. Sustainable compost utilisation - principles and application recommendations

Sustainable compost application means, that composts in the agricultural crop production may be used not in general, but only under certain conditions and considering agronomic rules for the application. Only like this, the necessary soil conservation and environment protection requirements may be connected wisely with the advantages and beneficial effects, i.e. the criteria for a sustainable application are guaranteed.

Table 3 shows **the summary of the agricultural compost application** in a summary packed form as well as the essential steps, that are necessary for technical arguable decision-making (detailed executions in addition in main report chapter C 1.3.3.1).

Table 3. Sustainable agricultural compost application - principles and steps for the decision-making.

Principles		
Conditions	**Application**	**Evaluation**
Law kept • Bioabfall-VO • Düngemittel-VO	Possible	“proper application “
Requirements for profitableness and harmlessness achieved	Useful	"good manufacturing practice“
Integration in crop rotation and production procedure guarantees	Practically feasibly	Include in the production system
Decision-making soil		
question to be cleared	**If yes...**	
a) Application in accordance with Bioabfall-VO possible? (Risk assessment)	• The heavy metal contents fall below the soil limit values **Better**: Heavy metal content in the soil clearly below regional background values	
b) Demand available? (Advantages assessment)	- Demand for organic matter exists - Humus balance negative - Humus content suboptimal - The soil conditions are suboptimal - Soil structure - Water balance - Soil biology - Erosion - Demand for nutrients (P, K, Mg) and lime exists - Nutrient contents suboptimal to optimal (content grade A to C) - pH factor too low	
Decision-making compost		
question to be cleared	**If yes…**	
a) Requirement Bioabfall-VO achieved? (Risk assessment)	• The heavy metal concentrations fall below the compost limit values **Better**: Heavy metal concentrations clearly below the limit values • The compost is practically free from weed seeds and free from Salmonella **Better**: absolutely free from weed seed	

	• The concentrations of foreign matters/ stones fall below the limit values **Better**: practically free from foreign matters and very low stone contents
b) Compost use? (Advantage assessment)	The requirements of the Düngemittel-VO (Fertilizer) are achieved: **Compost = of organic NPK fertilizers** with • Essential content in organic matter (30 - 50% of DM) • Nutrient contents higher than 0.5% of N, 0.3% P2O5 and 0.5% K_2O of the DM • Fertilizer effective lime content (4 – 8% of DM CaO)

In general compost may only be used in agriculture, if the “proper application” according to Bioabfall (biowaste)-VO and Düngemittel (fertiliser)-VO is guaranteed. The application makes sense, if the rules of good technical practice are kept, the utilisation is practicable and there are benefits to the farm. An optimum integration in the crop rotation as well as into the production system is favourable.

The professional decision-making has to consider the following steps to make sense (Table 3):

The first step is always to ascertain if the soil is generally suited for a compost application (risk assessment). Therefore the heavy metal concentration limit values have to fall short in accordance with the Bioabfall-VO. In the second step it has to be proven, that the soil needs "soil improvement", nutrients, organic matter and/or lime that could be covered by compost application (advantage assessment). The suitability has to be examined next for the available compost for the application. The compost must fulfill all risk criteria and all authoritative benefit effects must be proven. If all test criteria are answered positively, good conditions for a sustainable application exist.

The most optimal compost effects depend substantially on the observance of the according **application recommendations**. Additionally, essential criteria and basic conditions have to be checked and compared with experiences of practical farmers as well as scientific literature (Table 4, as well as more details in main report chapter point C 1.3.3.2).

To decide the amount of compost supply, the observance of well-balanced nutrient balances in phosphorus and potassium are important. The N_t supply (maximum 170 kg / ha) can also be a limiting factor. For these reasons the optimum compost supply vary on average around yearly 6 - 7 t / ha DM. For soils with insufficient supply of nutrients and/or unfavorable soil conditions (e.g. bad structure) higher compost supplies up to 10 t / of DM may be applied for several years, to provide fast improvements.

The experiments have shown the accumulative effect (once off) of compost application at 20-30 t/ha DM, do not result in agronomic advantages. They cause considerable nutrient excesses in the application year, i.e. increased leaching risks. Besides, the first crop receives an unnecessary "luxury supply" in nutrients, while the adequate supply of the

subsequent crops are not guaranteed. Nevertheless, the lower application costs and the lower travel on the field surfaces lead to a once off application.

The application of compost before sowing and planting are suited for varieties of grain and “Hackfrüchte” ‘root crops’ (for example as potatoes, sugar beets etc). Fresh composts are especially favourable for the application in autumn as they temporarily dissolve nitrogen in the winter period and leaching can be prevented. The application during frost with sufficient loading capacity on the soil is advantageous because soil compaction is avoided.

Compost should be mixed in shallow (maximum 5 - 10 cm), to ensure a quick breakdown of biodegradation. Deep mixing (plough furrow) should be avoided, because it may become anaerobic and roots may be damaged under anaerobic conditions.

Table 4. Rules for sustainable agricultural compost utilisation.

Criteria	Key number/ areas/ guidelines	Note
Calculation of the compost supply		
upper limits by law in accordance with Bioabfall (biowaste)-VO	• 20 t / ha DM all 3 years (upper limit for heavy metal limit values for composts) • 30 t / ha DM all 3 years (more stringent heavy metal limit values for composts)	
"Good manufacturing practice “in accordance with. Dünge (fertiliser)-VO	• Optimal annually 6 - 7 t / ha DM (20 t / ha DM all 3 years) • Maximal annually 10 t / ha DM (30 t / ha DM all 3 years)	**Important: well-balanced nutrient balance!** Limiting factor is the P and K fertiliser demand, as well as(limited?) N supply
Enrichment of the nutrient supplies in the fertilizer balance		
Phosphorus, potassium, Magnesium	Fully available?	with magnesium always high positive balance
Nitrogen	compost application – at short term (1 - 3 years): max. 5% – in the medium term (4 - 8 years): 10-15%	Huge variation in isolated cases Green composts: lower values Biocomposts: higher values
Suitable application appointments		
before sowing or planting	• Winter crop / catch crop: From August to September • Silage and ‘punch’ maize: From March to April • Potatoes / sugar beets: From February to March	Fresh composts suitable for autumn application: Immobilisation of residual nitrogen during winter period
Application during frost period	• January to February	Winter crop: Application on cropped field without problems Advantages: no soil compaction, quicker ground warming
Application tips		
Application intervals	• Cumulative all 3 years Advantage: lower application costs • annually	**Disadvantages of accumulated application**: Discontinuous supply in nutrients

	Advantage: more continuous supply of nutrients and resources, more balanced nutrient contents, more sustainable impact	and resources, for the first crop nutrient excesses and leaching danger, insufficient supply of the subsequent crops
Technical application	• Shallow mixing level (5 - 10 cm) • Erosion danger: mulch application without mixing into the soil	**Don't plough the compost into the soil!** Problem: anaerobic can cause root damage

A 2. Economic-ecological assessment

The assessment of the economic and ecological consequences of compost applications on agricultural land in the project report leads to a comprehensive overview about positive and negative effects that may be connected with a compost fertilisation.

Compost evaluation model (Kompostevaluierungsmodell: KEM) has been created, that takes into account the total results from the long term experiments of LUFA Augustenberg and many other known results of this topic. The model allows getting results beyond the present level of knowledge.

It is an economic, multidimensional model, where numerous marginal returns for different locations, business type, time periods and compost amounts are economically optimized to determine the internal effects. An additional ecological model is attached to charge external effects that consider all the environmental effects that are linked with the compost fertilisation.

A 2.1. Economic benefits for the agricultural operation

The results of the KEM (compost evaluation model) show, for nearly all the modulated cases that compost applications develop in the course of the application time positively in the economic regard. An assessment of the compost applications hence must occur always in the medium term, better even in the long term. The **marginal returns increases** are shown in the following tables, which may occur for compost applications on agricultural lands referring the results of the KEM. These values are based on a compost price of zero and a delivery of the compost free to the fields and the farmer is paying the application costs.

For all the **business types,** the crop farm is notably predestined for compost applications as table 5 points out. In the model after seven years of compost applications the annual marginal return increases of 78 €/ha are calculated, while this value for mixed farms is only 18 €/ha. Hence, from the economic view the available compost is proposed, primarily to be added on surfaces, where none or only less organic matter produced on the farm itself is added.

Table 6 shows, that for all the **locations,** the heavy soils profit the most of compost applications. Here are with long-term compost fertilisation annual marginal return

increases of 117 €/ha on average for crop farms possible, while on light soils with the same farming only marginal return increases in the scale of 53 €/ha are achieved.

Table 5 Marginal return increases supplying yearly 10 t / ha DM compost in dependence on different operating types – Average about all locations (all information in € / ha).

Operating type	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7
Crop farm	40	57	65	69	73	75	78
Mixed farm	7	11	13	14	16	17	18

Table 6 Marginal return increases by the application of yearly 10 t / ha DM compost in dependence on different soils for crop farms – without location Weierbach (all information in € / ha).

Soil Type	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7
Heavy Soil	59	80	92	100	106	112	117
Light Soil	24	36	42	46	49	51	53

Table 7 shows possible marginal return increases as a function of the amount of the annual compost supply in crop farms. The **optimum application amounts** (See main report point A 1.1) depend on the nutrient demand of the crops and the compost price, between 5 and 10 t DM per hectare and year. Decisively for the definition of the exact application amounts is the price, which is determined by the compost producers. If the price rises, it is worthwhile for the farmer reaching a certain price level, to reduce the compost application amount. Smaller amounts as 5 t DM per hectare and year are not worthwhile on account of the high application costs. While higher supplies than 10 t DM per hectare and year are not allowed in accordance to the Bioabfall-VO as well as to the Dünge-VO.

Table 7 Marginal return increases as a function of the height of the annual compost supply in crops farms – without the location Weierbach (all information in € / ha).

Compost Supply	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7
5 t / ha DM	38	48	52	53	54	55	55
10 t/ha DM	53	78	90	97	102	106	108

The economic consequences of compost fertilisation are **summarised** in Table 8. It becomes clear, that long-term annual compost supplies have substantial bigger economic advantages, than one application of compost supply. Besides, the economic benefits for heavy soils and in crop farms are shown in this Table 8.

Table 8 Assessment of the economic consequences for a unique and a long-term (7 years) annual compost supply of 10 t / ha DM as a function of the operating type and soil type.)

Compost Application	Operation Type	Soil Type		
		Slightly	Medium	Hard
One time Compost Supply	Crop farm	0	+	+
	Mixed farm	0	0	0
Long Term Annual Compost Supply	Crop farm	+	++	+++
	Mixed farm	0	0	+

Legend: +++ Rise of the gross margin by more than 90 € / (ha*a)
++ Rise of the gross margin by more than 60 € / (ha*a)
+ Rise of the gross margin by more than 30 € / (ha*a)
0 low positive consequences on the gross margin

A 2.2. Consequences of compost applications on the environment

To take the ecological consequences of compost applications on agricultural land into consideration, it becomes clear, that negative, as well as positive external effects appear. Possible negative external effects may be a gradual enrichment in the soil and the crop products with heavy metals and organic pollutants. This supports the importance of regular soil and compost analyses towards pollutants for the long-term production of safe food (sustainable compost application).

Table 9 summarises the modulated results from the model for the possible **reaching of heavy metal limit values in the soil**. The table documents clearly, that for an expert assessment it is essential for this risk to differentiate between the single heavy metals. For the toxic heavy metals Cd, Cr, Hg, Ni and Pb the enrichment in the soil is very low and therefore tolerable. But higher enrichment rates and therefore shorter periods to reach the limit values for Zn and mainly for Cu are under the point of view that both heavy metals are also essential trace nutrients and obligatory needed from plants (See main report point A 1.2) and not only valued exclusively as a risk.

It has to be considered that the introduced risk evaluation is valid for the model on six test locations and their heavy metal contents in the soil before the first compost supply. A generalisation on all agriculturally used soil is only possible with restriction. Thus the enrichment periods to reach the limit values are substantial longer for lower initial contents of Cu and Zn, than shown in Table 9, i.e. the risk becomes increasingly tolerable. With a deficit of these trace elements enrichment is even welcome in the soil and is valuated positively.

Unconditionally valid and able to be generalised is the difference between the operation types, that result clearly from the model results. Crop farms without compost application come of the best. Farms with their own organic fertilisation are advised in general not to use compost supplies, as the heavy metal enrichments of both organic fertilizers add up.

Table 9 Possible reaching of heavy metal limit values in the overview – average about all modelled locations by consideration, the respective heavy metal contents in the soil before the first compost application.

Compost Supply	Operating Type	Heavy Metals						
		Cd	Cr	Cu	Hg	Ni	Pb	Zn
Without Compost	Crop Farm	0	0	0	0	0	0	0
	Mixed Farm	0	0	--	0	0	0	--
10 t / ha DM	Crop Farm	0	0	-	0	0	0	-
	Mixed Farm	0	-	---	0	0	0	--

Legend: o tolerable, no limit value reaching during the next 200 years
- at the short term tolerable, no limit value reaching during the next 100 years
-- critical, no limit value reaching during the next 30 years
-- very critical, limit value reaching within the next 30 years possible

To take in account the **erosion,** the long-term humus fertilisation with compost is valued very positively, as it has to clearly decrease in all cases. However, in certain cases, as for very steep inclinations, other erosion preventive measures are necessary. Table 10 puts the erosion problems for crop farms into account of different slope angles.

The **formation of climate relevant gases** may be somewhat reduced in most cases with compost application. With the new developed models, we are able to determine the monetary value of the reduction of harmful gases. Table 11 gives an impression about the value per ton of compost in the single application years. As with the production of other fertilisers, gases relevant to the climate are produced and these can be saved up only after some years and in larger amounts. This is caused by the delayed nutrient availability of the compost and the monetary value of the emission decrease rises continuously.

Pollutions of ground and surface water are caused by an improper fertilisation with the basic nutrients. To judge the effect of compost supply on those problems a balance of the nutrients at farm level was implemented in the KEM. Table 12 shows a value display of the nutrient excesses. On the basis of the results, the compost fertilisation should only be applied in crop farms that do not hold their own organic substances.

Table 10 Display of the erosion problems in crop farms for the variations K0 (no compost) and K2 (10 t / ha DM compost) with different slope inclinations.

Compost Supply	Slope Inclination in %					
	0	2	4	6	8	10
Without Compost	+	o	-	--	--	---
10 t / ha of DM	+	+	+	o	-	--

Legend: + positive, profit potential in the long term secure
o tolerable, profit potential for at least 400 years secure
- At short notice tolerable, profit potential for at least 200 years secure
- Critical, profit potential for at least 100 years secure
--- Very critical, reduction of the profit potential within the next 100 years probably

Table 11 Monetary value of the decrease of climate relevant gas emissions with a once annual compost application of 10 t / ha DM form crop farms – converted on one ton of compost (all information in €).

Compost Supply	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7
10 t / ha DM	0.1	0.59	0.82	0.95	1.03	1.09	1.14

Table 12 Assessment of the long-term nutrient excesses after on-farm organic fertilisation and compost supply – average about all locations.

Compost Supply	Operating Type	Nutrients		
		Nitrogen	Phosphate	Potassium
Without Compost	Crop Farm	+	+	+
	Mixed Farm	+	+	+
10 t / ha DM	Crop Farm	+	+	o
	Mixed Farm	+	-	--

Legend: + positive, in the long term no danger for over-fertilization
0 tolerable, dangers for over-fertilization clearly under the average
- At short notice tolerable to increase the fertilization of the soil when required
-- Critical, only tolerable for very short term increasing of the fertilization of the soil

In Table 13 all ecological consequences of the compost applications are shown summarised. For the compost application in crop farms the positive effects predominate the risks by far, while for farm types with cattle breeding the positive effects are a little lower and negative ecological consequences increase.

Table 13 Summary assessment of the ecological consequences of a long-term annual compost supply of 10 t / ha DM in crop farms and mixed farms.

Parameter	Crop Farm	Mixed Farm
Heavy metal content in the soil	-	--
Heavy metal content in the grain	O	O
Organic pollutants in the soil	O	-
Organic pollutants in the grain	O	O
Erosion	++	++
Gases relevant for the climate	+	O
Water pollution	O	--

Legend: ++ very positive ecological consequences
+ Small positive ecological consequences
O to classify neutral, neither positive nor negative
- Tolerable, long-term negative consequences possible
- Critical, only very at short notice tolerable

A 2.3. Total appraisal

Finally it can be ascertained, according to these extensive investigations, that compost utilisation on agricultural farms is recommended from the economic and ecological points of view. If the compost is used in the right way, the negative external effects are minimised and the positive environmental effects are maximised. To reach this and to develop and to extend the circulatory farming also in the future, these project results give a comprehensive guide to the compost manufacturers as well as to the relevant farmer, thus leading to economic and ecological sensible compost utilisation.

A 3. Marketing strategies

The results of the segments A1 and A2 prove that high qualitative, quality guaranteed composts may be used profitably and environmentally for horticultural agriculture by the observance of certain basic conditions. The main targets of the partial project "marketing strategies", on the background of the ascertained advantage effects, have been to make enquiries and to compile suggestions, to improve the basic conditions for compost applications in the agriculture.

In an analysis of the compost sales area the mental attitudes, wishes, reservations and fears of the target group agriculture were acquired. Therefore farmers were questioned verbally as well as in written form nationwide for the compost utilisation in agriculture. Relevant data about the structure of the agricultural farms, the advantages and disadvantages of compost applications, the relations between user and producer and the acceptance of agricultural compost utilisation were acquired. Farmers with experiences in compost applications have been included as well as those without experiences with compost till now. The questionnaires were addressed to 1400 farmers and of those 224 forms were used for the evaluation.

In addition, 23 selected compost producers (members in the Bundes-Gütegemeinschaft Kompost - BGK) were questioned about their marketing activities until now, in particular to underline the practice relation of the recommended measures.

Based on these market analyses and the economic and ecological results, afterwards the possibilities of different marketing instruments were indicated and involved in an integral marketing concept.

A 3.1. Results of the market analyses

While **questioning the farmers,** mainly their mental attitudes, wishes, reservations and fears, but also last but not least their expectations were addressed, concerning compost utilization on their fields. Although more than 50% of the questioned farmers use compost, numerous reservations were mentioned, that are briefly summarised below:

- Doubts concerning quality (pollutants, hygiene, foreign matters)
- Unsafe legal circumstances (depreciation for lease or sales, marketing problems of the products)
- Insufficient acceptance of the general public
- Deficits of information
- Financial reimbursement (only 20% of the farmer bought the compost at the price, 47% of thought the price was unacceptable and took it the compost for free and 14% had to pay the farmers to take the compost)
- Insufficient services

The positive expectations named by the farmers correspond to the possible effects that may be expected using compost fertilisation after the present project results. First, the soil improving effects were called here, but also the fertilisation effects and the possible decrease in erosion.

The people surveyed were **compost producers** who were members of the BGK, that produce compost predominantly in windrows and produce mainly (three quarters) bio-waste composts with “RAL-Gütesicherung” (RAL quality assurance scheme). About 43% of those produced composts are delivered to the agriculture. The questioning of the actual situation in the compost producing companies delivers the following results:

- Transport and/or application are offered by almost all producers, mostly for free.
- All producers use external reports (FÜZ) as quality certificates. In addition, a further consultation (agricultural consultant) is offered of most enterprises.
- 64% of the producers already request a price, while 36% deliver the compost for free and 14% pay extra for the delivery.
- In the area of communication it was ascertained, that no market researches have been done on agricultural utilisation. But a very distinctive information exchange with their own federation as well as with the sciences, policy and agricultural professional helpdesk takes place. Often used communicative devices are booklets of the federation, scientific articles, “open days“, as well as authoritative farmers.
- These are the current targets are as follows: Additional payments should be reduced in future and the current prices should remain at least at the same level. These moderate price increases should be accompanied by a continuous optimisation of quality.

A 3.2. Marketing strategies

A 3.2.1 Marketing instruments

Based on the economic and ecological results as well as on the market analyses, recommendations for possible marketing measures were developed.

Recommendations for the product and assortment policy

- Based on the analysis of the marketing area agriculture depending on the operating type, location and application amount, a concentration on the target groups has to be derived, where the positive economic consequences are relatively largely and the negative ecological impacts are small or do not even appear. Hence, as the main marketing group initially follow crop farms on medium to heavy soil.
- The supply should be aimed on the regional demand structure and the specific circumstances of the compost plant.
- In general only high-quality composts should be offered, that is due to have high beneficial effectiveness for sustainable application and thus also reflect the monetary value of compost.
- Clear application recommendations and product declarations are necessary as well as strict high-quality obligations and quality inspections within a closed controlling chain.
- Excluding the sector of special cultures, the necessity of a product diversification in the agricultural compost utilisation is classified rather low.
- The gradation of fresh compost (Frischkompost) and matured composts (Fertigkompost), regardless of the kind of compost, should be replaced by a systematic evaluation of compost for nutrient and material contents.
- A tight interlocking of the product and assortment policy with the communication policy is essential.

Recommendations for the price policy

An essential argument in the price policy is the economic advantage of compost supply.

In conclusion, the higher the difference between the price and the calculated marginal return increase, the more the argumentation need increases (Table 14).

An additional payment should be avoided in general. If, at the present, delivery is free it is recommended, to increase the price only that high, that the farmer may expect already in the first year an increased profit by the calculated marginal return increase per hectare, with the knowledge of the positive effects for the subsequent years. Attempts of price differentiation as well as the application of price-policy are possible (e.g. special offers for the special crop area, loyalty discounts, and compost application on test).

Recommendations for the service and distribution policy

Offer of transport and application

In conclusion, the willingness to use compost often depends on the acceptance of the transport and the application by the compost producers. The farmer often expects a free delivery to the field.

Ability to deliver

As the agricultural application of compost often depends strongly on the weather conditions, sufficient amounts have to be available on a very short term. Above all the adaptation on demand peaks that exist in the spring before sowing or during harvesting has to be taken into consideration.

Consultation

The consultation is an essential tool to develop confidence between producer and user. Possibilities of compost applications have to be brought close to the farmer and his state of knowledge and his basic attitude to the agricultural utilisation have to be considered.

Table 14 Argument to provide achieve a price for the target groups.

Target group	**Argument for Demand**			
	Low	High	Very High	Due to Economic Reasons Impossible
	if the price is up to the value in the first application year	if the price is up to the average value on more than 7 years application duration	if the price is between the average value on more than 7 years application duration and above the highest single year value	If the price is higher than the highest single year value
MF – s	price < 5.90 €/t	< 9.50 €/t > 5.90 €/t	> 9.50 €/t < 11.70 €/t	> 11.70 €/t
MF - s/m	price < 5.80 €/t	< 7.80 €/t > 5.80 €/t	> 7.80 €/t < 8.10 €/t	> 8.10 €/t
MF - s/m/l VFG – s	Price < 2.40 €/t	< 4.20 €/t > 2.40 €/t	> 4.20 €/t < 5.30 €/t	> 5.30 €/t

Hint: The prices are based on the results of the economic assessment per 10 t application amount (price round on 10 cents).

Legend: MF – s “crop - heavy soils“
MF - s/m „ “crop - heavy / medium soils“
MF - s/m/l “crop - all soils “
VFG – s “upgrading/ feedstock production/ mixed (Veredelung/Futterbau/Gemischt) < 80 kg N / ha - heavy soils “

Recommendations for the communication policy

The communication policy has an outstanding importance for compost marketing. It contains the following major tasks and their implementation (Figure 1).

The differentiation is important between general clarification, for farmers, but also for authorities and in the end for the public in general and more specific user information. Accordingly the communication instruments are divided in "group marketing" and “individual marketing (Table 14).

To reach a maximised efficiency of the used marketing instruments, several instruments should be used in combination with synergy effects (marketing mix).

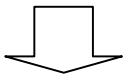
A 3.2.2 Marketing concept

For a sustainable success the marketing activities should be integrated in a compact concept (See Figure 2).

Figure 1 major task of the communication policy and their conversion.

Major tasks of the communication policy

- Clear reservations!
- Image improvements!
- Clear clarification of the advantages!
- Dismantling of the uncertainty (pollutants / judicial situation)!
- Creation of confidence / customer loyalty!
- Contribute to the fulfillment of the complete goal!



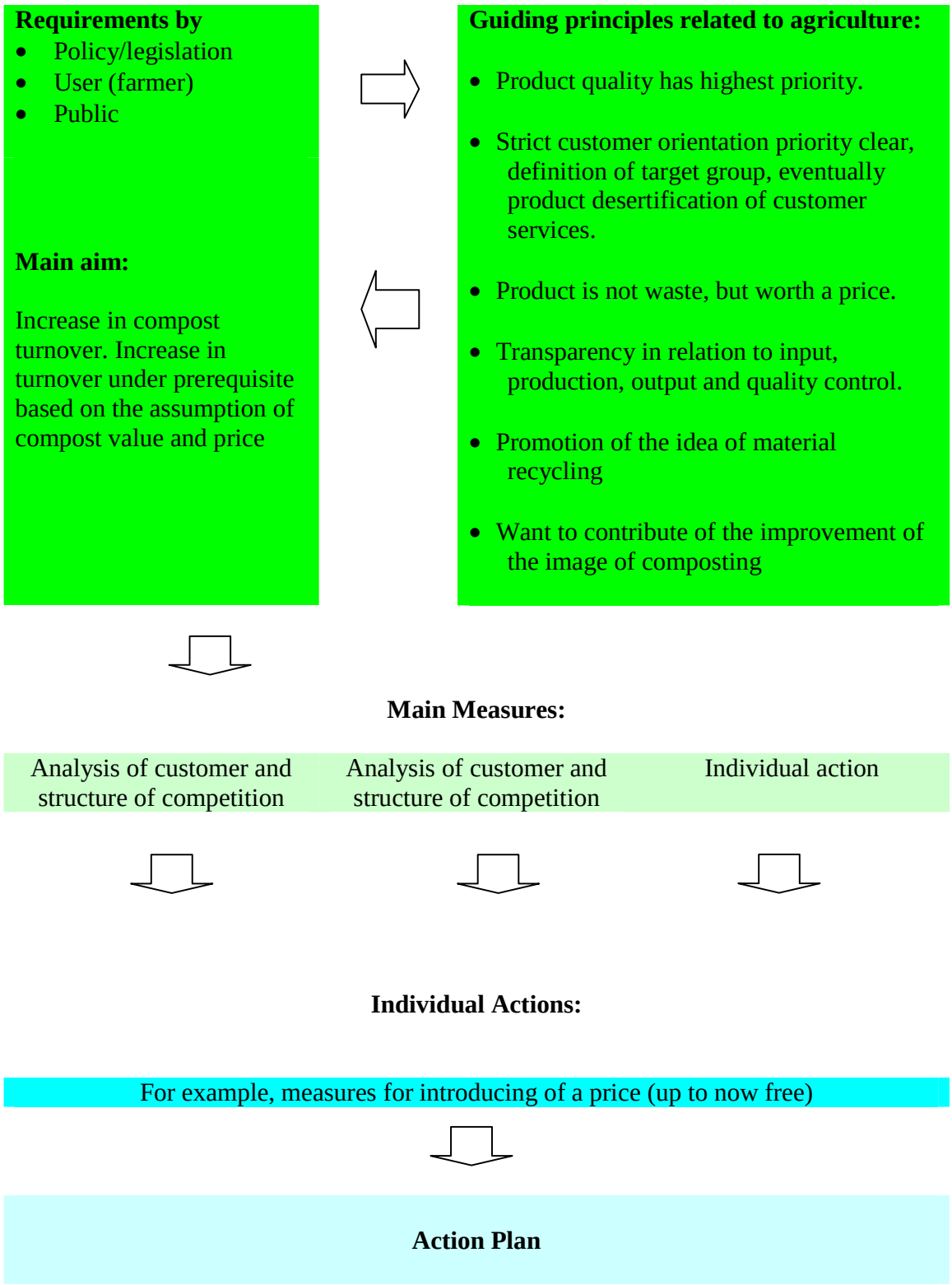
Conversion of the major tasks

- Specific factual information’s
- Explicit declaration of the nutrient and pollutant contents
- Indicate of qualities / application recommendations
- Transparency of economic and ecological impacts
- Feature a complete controlling chain
- Clarification of the consumer / of the public
- Support of the environmental and consumer protection mind (protection of resources)

Table 15 Classification of the communication instruments in group marketing and individual marketing.

Group marketing	Individual marketing
• Editorial reports • Factual information (e.g., in pamphlets, internet) in informative, summary and demonstrative form with clear display of the research results • Mediation of information to authorities and opinion leaders • Uniform market appearance of the enterprise group • Development of a slogan	• Editorial reports, announcements • Web site, pamphlets etc., transfer of contents from the enterprise group • Direct Mailings • Use of multipliers to the mediation of information's to farmers (e.g., Maschinenringe, reference farmers) • "Consulting tables" to exchange information's between farmers, consultant engineers and compost producers • Presenting of information during "open days", field inspection, events, exhibitions, conferences, presentations

Figure 2 Construction of a marketing concept.



A 3.3. Concluding whole appraisal

The group-research project shows unambiguously the economic and ecological consequences of a compost application on agriculture and quantifies them. It is clearly worked out, that

- Compost is a valuable humus and nutrient fertiliser, that justifies a price,
- Compost application are predestined for crop farms on medium to heavy soil
- Quality guaranteed composts implement the requirements on soils in general better than other composts due to comprehensive high-quality controls. Essential for the agricultural compost application are strict controls of all necessary quality requirements.

The positive effects of agricultural compost applications have been determined persuasive, but there are also disadvantageous sales obstacles. Uncertainties and fears within the agriculture often prevent a compost application. If the aim of all (marketing) efforts, the "increase of compost applications considering prices based on the compost value“ should be reached, a marketing concept – starting on the analysis of the target group and the basic conditions - all suitable marketing instruments have to be taken into consideration and have been adjusted to the assignment. The communication policy is essential for an objective representation of the advantages and to clear reservations and fears of possible. This clarification work is for farmers (individual marketing), as well as for authorities, agricultural lobbyists, politicians and, in the end to the public in general (group marketing). Task of the individual marketing as well as the group marketing it is to spread the explicit results of this group-research project:

Agricultural compost utilisation - economical and sustainable!

A 4. Operation recommendations

The DBU group research project **presents** the first time comprehensive results based on representative compost essays for several years, answering a wide range of open questions of the agricultural compost application, agronomic evaluation, validation of economic advantages and the ecological consequences and also suitable strategies for compost marketing.

The examination of the agronomic advantageous effects of the agricultural compost utilisation in consideration with the possible risks has shown, that implementing of "good manufacturing practice“ for compost application, considerable saving potentials may be used for farms, mainly for the fertilisation and soil improvement. Assumed adverse effects on the soil and the quality of the harvest products are avoidable.

The **compost producers (communal and commercial companies)** are challenged to implement adequate tasks, to improve the qualities of the produced composts and therefore to ensure a sustainable agricultural composts application in the future. Specific

publicity and suitable marketing strategies may improve the compost utilisation acceptance of farmers.

The following recommendations can be given:

- Continuous decrease of heavy metal contents of composts by specific use of basic materials with low heavy metal contents (e.g. mainly plant waste) with the aim to go below the limit values the Bioabfall-VO even further than up to now.
- Continuous improvement of the phyto-hygienic and epidemic-hygienic qualities of the composts. Therefore beside the regularised absence of *Salmonella* also compost completely free of weed seed may be guaranteed.
- Further decrease of the foreign matter contents to obtain a good optical appearance for compost applications. This means a clear shortfall of the limit values, in fact a total absence of foreign matters.
- An even improved guarantee for the declared nutrients and resources contents with the purpose, to apply composts optimal for fertilisation and resource balances of a field or the farm.
- Strict observance of the quality guidelines of composts and a quality control within a cohesive controlling chain.
- Differentiated address of the target group agriculture according to the operating type, location and application amount.
- Increased consultations and specific publicity with the purpose, to point out as objectively as possible, advantages and possible risks of the compost utilization.
- To bring out compost as a valuable product, whose benefits become apparent mainly for long-term application
- Offering of services concerning the compost application.

The users, the farmers (and also the landscaper) require a high specialist competence for a sustainable compost application. With a specialist challenging application, they are not only able to influence their operating results positively, but also to contribute decisively to the better acceptance of compost applications in the public.

For the compost consumer the following recommendations may be considered:

- The agricultural application occurs only if there is a requirement of nutrients, lime and/or organic matter in the soil and in case the heavy metal contents in the soil fall clearly below the limit values.
- Composts initially used on farms with negative humus balance, as crop farms, where clearly positive economic consequences, as well as minimised ecological risks may be expected. Applications on locations with heavy and medium soil have especially high economic advantages.
- Quality guaranteed composts guarantee higher quality requirements than those only bound by law. This warrants a profitable and environmental application and therefore should be preferred.
- The "good manufacturing practice“ has to be considered, in particular concerning the calculation of the fertilization amount of the plant (well-balanced nutrient balance) as well as the application at a suitable time and according to proven rules.

- Opinion forming and the exchange of experience for the compost application in the agriculture should be advanced. Improved utilisation of all offered information possibilities, in particular via current scientific research results.

  Extended and professional desired compost applications in the agriculture depend exceedingly on adequate influencing **of legislator and administrative execution.** For both areas the following recommendations arise out of the project results:

- A further intended decrease of the heavy metal limit values in the Bioabfall (biowaste)-VO for composts has to consider the available production and application possibilities. Drastic reductions, towards the principle ‘similar to similar’, that are in discussion of the environment national department, are not comprehensible from the professional point of view. A possible consequence would be an extensive pullout of the agricultural compost utilisation, with all disadvantageous effects on resource protection (particularly phosphorus), without existing a necessity from the professional point of view. The soil conservation and consumer protection is also guaranteed in the long term without these efforts, as pointed out in these project results.
- For special cases, as renovation of soils with humus contents and nutrient contents that are too low, higher compost supplies than the legal maximal supply of 30 t / ha TM may be permitted. **Using well-chosen composts with high valuable substances (particularly organic matter) and low heavy metal contents, no risk exists for soil conservation and water pollution protection, even using a single compost supply of up to 60 t / ha DM.**
- Determined definitions of limit values for undesirable substances and application restrictions by law it have to be balanced intensively with the ecological benefit effects. Ecological advantages and the ecological risks must be deliberated objectively.
- A clear and uniform regulation by law for compost applications in the agriculture, based on scientific knowledge, contribute to the dismantling of the widespread uncertainties in the agriculture and promotes, in the end, a holistic approach by law.

In spite the comprehensive project handling with long term compost tests over several years' another **research effort is needed**, mainly the long term effects of composts, that may be cleared in particular doing further compost long term tests:

- So for example, the long-term N-mineralization quality (> 10 years) has to be determined. This knowledge, as a function of the location an operating type would contribute to consider more precisely the mineralised N content of composts in the N-fertiliser balance. This is conductive to soil conservation (avoidance of too high nitrate concentrations) as well as to the profit optimisation (optimum N fertilisation).
- All "soil-improving" compost effects on the soil structure and the soil-biological conversions as well as the water balance require longer observation periods, than were available in the present project. The specification of the presented research results would considerably contribute to a more goal-orientated use of compost for soil improvement.
- A time period of seven years may be modelled reliably with this project results. The agricultural practice already wished an even longer modelling duration, for a better

evaluation of the economic benefit effects in the long term. This requires a consequent continuation of the long term compost tests and the necessary investigations.

- Under marketing points of view it is necessary to do regular market observations. That is the only possibility to determine, whether and how the suggested marketing tasks are used and the aimed purposes are reached.

The Following Two Pages are a Summary of the Entire Research

Research project of the German Environmental Foundation

UMWELT STIFTUNG

Sustainable use of compost in agriculture

Research results of a long term study in the Federal Republic of Germany (1)

1. Savings potential of fertilization

Amount of biowaste compost or garden compost of
- annually 7 t DM/ha or 12 t GM/ha
- every 3 years 20 t DM/ha or 30 t GM/ha

DM - dry matter GM - green matter

results in the following annual **savings potential:**

➢ **Application of 2.5 - 3.5 t DM/ha of organic matter:** conservation and promotion of humus content of soil

➢ **Supply of nutrients and lime:**

Nitrogen	N	90 – 130	kg/ha
Phosphorus	P_2O_5	50 – 70	kg/ha
Potassium	K_2O	70 – 110	kg/ha
Lime	CaO	3.0 – 4.0	dt/ha

➢ **Average balance of nutrient intake/removal** (cf. Fig. 1): Usually balanced with nitrogen and phosphorus, but significantly positive with potassium and especially magnesium

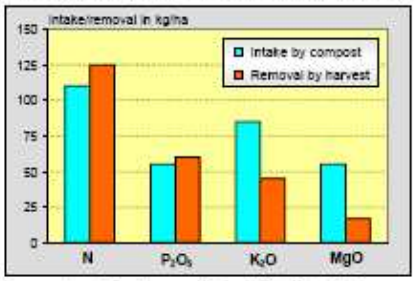


Fig. 1: **Example of balance of nutrient intake/removal:** Compost amount: 20 t DM/ha every three years Crop rotation corn/grain: average removal

➢ **Amount control of nutrients and lime in the fertilizer balance:**
- Phosphorus and potassium fully accountable, i.e. **saving of basic fertilizing** Note: both nutrients constitute the limiting factor for the amount of compost application!
- Nitrogen at the beginning annually only up to <5 %, in medium-term 5 – 15 % accountable, i.e. supplementary fertilization with nitrogen absolutely essential despite high N supply with compost, reduce N-amount accordingly
- Application of lime stabilizes the soil pH value, i.e. **additional preservation liming unnecessary**

2. Advantages for crop production

➢ **Significant improvement of soil structure, hydrological balance and soil biology:**
- Increase of soil crumb stability: Compaction protection, increase of soil resilience, improved traffic tolerance and **erosion protection**
- Bulk density of soil is reduced: Improved aeration and drainage
- Increase of field capacity: Higher moisture reserves during drought
- Moisture infiltration of soil rises: Improved water absorbing capacity and permeability during heavy precipitation
- Improved soil biology: Overall activation of earth life

➢ **Gradual optimization of all important soil properties:** Especially of soils with poor structure (clay) are activated and become more utilizable, erosion of endangered areals is reduced (erosion protection), increased drought resistance of plants

➢ **Increased stabilization of yield and gradual increase of crop yield level typical for the location:**

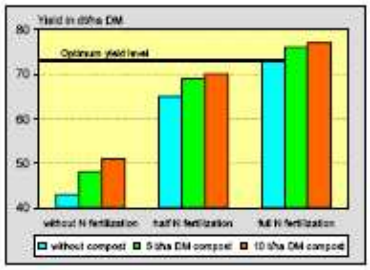


Fig. 2: **Significant results after compost application:** Average annual yields at 4 locations over a period of 6, resp. 9 years

Result: Significant increase of yields with 5 to 10 t/ha DM compost application including supplementary nitrogen fertilization (cf. Fig. 2).

➢ **Economic advantage resulting from reduction of min. fertilizers, costs and through increasing yields:** Additional contributing margins of annually 30 - 80 €/ha, at heavy soils up to 120 €/ha achievable for cash crop enterprises, soil quality improvement reduces cultivation machinery fuel costs

Final report of the GEF project: November 2003

Research project of the German Environmental Foundation

Sustainable use of compost in agriculture

Research results of a long term study in the Federal Republic of Germany (2)

3. Possible problems (risk evaluation)

- **Heavy metals**
  - **Heavy metal content of guaranteed quality compost** fall significantly below the limits of the biowaste directive (cf. Fig. 3)
    Note: Also control the heavy metals level of the compost

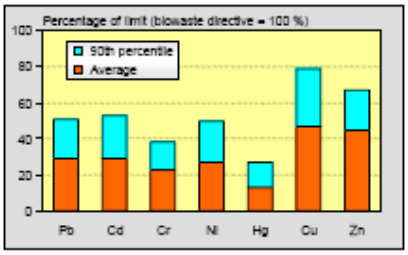


Fig. 3: Heavy metal content of composts in % fall below the limits of the biowaste directive

  - **Amount of heavy metals in soil**
    - ✓ Total concentration does not increase after application of compost in the medium-term (10 - 20 years)
      Note: Control the level of heavy metals at intervals of 10 - 20 years
    - ✓ "Mobile" (= soluble) content remains unchanged (Pb, Cr, Cu) or show reduced levels of concentration (Cd, Ni, Zn) after application of compost

  Therefore: sudden increase in the mobility of heavy metals in the soil need not be feared

  - **Heavy metal concentration in plants** remain unchanged following use of compost
- **Concentration of organic pollutants,** such as polychlorinated biphenylene (PCB) and dioxins (PCDD/F), are as a rule within the harmless range
  Note: Control the concentration within intervalls
- **Nitrogen mineralization of the compost biomass** always takes place very slowly (cf. Point 1, nitrogen amount control), no rapid increase of nitrate concentration in the soil was observed, i.e. groundwater protection is guaranteed
  Note: Control the N-min concentration of the soil regularly
- **Absence of impurities and stones** is guaranteed with the application of controlled quality compost, very low levels observed
  Note: request control results of your supplier
- **Annihilation of pathogenic agents and germinable weed seeds** is guaranteed with correct composting (hot rotting at min. 55 – 65 °C)
  Note: Control the temperature log of hot rotting, and request results of weed seed test in the compost material

4. Rules for sustainable use of compost

- **Apply compost only when indicated by soil requirements**, i.e.
  - too low level of nutrients (fertilization required)
  - too low level of humus content, negative humus balance (organic substances required)
  - unfavorable soil condition (poor structure, too high compression, too low field capacity, low level of microbiological activity)
  - erosion protection
- **Use only high-quality composts** which guarantee high concentration of valuable substances, low amount of pollutants, optimized sanitation
- **No usage of compost on soils with increased heavy metal load!**
- **Observe the concentration of phosphorus and potassium as the limiting factor for usage**
- **Smaller annual amounts of 6 – 8 t DM/ha are more beneficial than large amounts for several years**
- **Suitable crops for the crop rotation:** Corn, root crops, vegetables and grain
- **Observe suitable period of time for application:** Early spring prior to cultivation, preferably on frozen ground to avoid soil compaction
- **Notes on application**
  - **Fertilization as a priority** Incorporate nutritious composts with grain size up to 20 mm superficially only
  - **Optimization of soil quality as a priority** Mulch with composts with grain size up to 40 mm, **do not incorporate!**

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