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Comparative Life Cycle Assessment of Geosynthetics versus Conventional Construction Materials

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Executive Summary 2019

"Comparative Life Cycle Assessment of Geosynthetics versus Conventional Construction Materials"

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Goal and Scope Definition

Geosynthetic materials are used in many different applications in the civil and underground engineering. In most cases, the use of geosynthetic material replaces the use of other materials. In 2010, the European Association of Geosynthetic product Manufacturers (EAGM) commissioned ETH Zürich and ESU-services Ltd. to quantify the environmental performance of commonly applied construction materials (such as concrete, cement, lime or gravel) versus geosynthetics. To this end a set of comparative life cycle assessment studies were carried out concentrating on various application cases, namely filtration, foundation stabilised road, landfill construction and slope retention. The environmental performance of geosynthetics was compared to the performance of competing construction materials used. The specifications of the four construction systems were established by the EAGM members representing the European market of geosynthetic materials. They represent best current practice.

Tab. S. 1: Overview of the objects of investigation

Description	Alternatives	Case
Filter layer	gravel based filter	1A
	geosynthetics based filter	1B
Road foundation	conventional road (no stabilisation needed)	2A
	geosynthetics based foundation	2B
	cement/lime based foundation	2C
Landfill construction	gravel based drainage layer	3A
	geosynthetics based drainage layer	3B
Slope retention	reinforced concrete wall	4A
	geosynthetics reinforced wall	4B

The study adheres to the ISO 14040 and 14044 standards. A critical review was performed by a panel of three independent experts. The study refers to the year 2009. Foreground data about geosynthetic materials gathered by questionnaires refer to the year 2009 or, in a few exceptional cases, 2008. Data available about further material inputs and about the use of machinery are somewhat older. All data refer to European conditions.

The alternatives in each case were defined such that they can be considered technically equivalent or at least comparable. The geosynthetics used in the four cases represent a mix of different brands suited for the respective application. The conventional systems represent the most common type of construction.

The environmental performance was assessed with eight impact category indicators. These are Cumulative Energy Demand (CED), Climate Change (Global Warming Potential, GWP100), Photochemical Ozone Formation, Particulate Formation, Acidification, Eutrophication, Land competition, and Water use.

In order to evaluate the uncertainty of the data used, Monte Carlo analyses were performed. The Monte Carlo analyses were performed in a way that excludes depending uncertainties. The results of the analyses show the effects of the independent uncertainties of the two alternatives compared. The lifetime and the technical specification (layer thicknesses etc.) of the different constructions were not included in the uncertainty assessments. However, uncertainty due to variability in gravel density and in matching the thickness of the layers (95 % interval of +/- 7 %, or about +/- 3.5 cm for a 50 cm gravel layer) or of transport services required (95 % interval of about + 100 %/- 50 %) was taken into account.

Sensitivity analyses were carried out to further explore the reliability of the results. On one hand the thickness of the filter was varied in case 1 taking into account different technical specifications. On the other hand four alternatives for road foundations were analysed in case 2. This includes 2 alternative road foundations using reinforcement with geosynthetics and two alternatives for the stabilisation of the road using cement or quick lime only.

Object of Investigation and Inventory Analysis

The functional units of the four cases are distinctly different. That is why the results of the four cases should not be compared across cases.

Filter layer: The function of the first case is the provision of a filter layer. Geosynthetics can serve as separator or filter layer between the well compacted foundation and the subgrade. This is essential to make sure the foundation keeps its bearing capacity. The geosynthetic prevents on one hand the foundation aggregates from sinking into the subgrade and on the other hand from pumping of fines from the subgrade into the foundation.

The functional unit is thus defined as the construction and disposal of a filter with an area of 1 square meter, with a hydraulic conductivity (k-value) of 0.1 mm/s or more and a life time of 30 years.

Foundation stabilisation: In the second case concerning the improvement of weak soils, a conventional road, where no stabilisation is needed (case 2A), is compared to a geosynthetic reinforced road (case 2B) and to a cement/quicklime stabilised road (case 2C).

The function of the second case is the provision of a road class III on stabilised foundation. The functional unit is thus defined as the construction and disposal of a road class III with a length of 1 meter, a width of 12 meters and a lifetime of 30 years.

Landfill construction: The third case compares the use of a geosynthetic drainage system (case 3B) with a gravel drainage system (case 3A) in a cap of a waste landfill site. A geosynthetic on top of the drainage gravel is often used to prevent moving of fines of the top soil into the drainage, and a second geosynthetic is used below the drainage as a protection layer to secure that the sealing element is not damaged to the drainage. Hence, in practice both solutions use geosynthetics - on top of and below of the drainage layer. All the other layers in a landfill site change neither in thickness nor in material requirements.

The function of case 3 is to provide a drainage layer in a landfill cap of hazardous/non-hazardous waste landfill site. The purpose of this drainage layer is to discharge infiltrating rainwater from the surface. The functional unit is defined as the construction and disposal of 1 m^2 surface area drainage layer with a hydraulic conductivity (k-value) of 1 mm/s or more and an equal life time of 100 years.

Slope retention: It may be necessary in some cases, especially in the construction of traffic infrastructure, to build-up very steep walls. For such walls, supporting structures are necessary. The retaining walls need to meet defined tensile and shear strengths. Retaining walls reinforced with concrete (case 4A) are compared to soil slopes reinforced with geosynthetics (case 4B).

The function of the fourth case is to provide a slope retention with a very steep and stable wall. The functional unit is defined as the construction and disposal of 1 m slope retention with a 3 meters high wall, referring to a standard cross-section. Thus, the functional unit is independent of the length of the wall.

For all cases, data about geosynthetic material production were gathered at the numerous companies participating in the project. The company specific life cycle inventories were used to establish average life cycle inventories of geosynthetic material. Average LCI were established per case on the basis of equally weighted averages of the environmental performance of the products manufactured by the participating member companies. The technical specifications of the four cases (e.g. how much gravel and diesel is required) were verified with civil engineering experts. The materials and processes needed to erect the constructions were modelled with generic, background inventory data. The primary source of background inventory data used in this study is the ecoinvent data v2.2 (ecoinvent Centre 2010), which contains inventory data of many basic materials and services.

Results

In Fig. S. 1 to Fig. S. 5 the environmental impacts of the full life cycle of the four cases are shown. For each indicator, the environmental impacts of the alternative with higher environmental impacts are scaled to 100 %. The total impacts are divided into the sections infrastructure (road, landfill, slope retention), raw materials (bitumen, gravel, geosynthetic layer, cement, quicklime, concrete, reinforcing steel, wooden board), building machine (construction requirements), transports (of raw materials to construction site) and disposal (includes transports from the construction site to the disposal site and impacts of the disposal of the different materials).

A filter using a geosynthetic layer (case 1B) causes lower impacts compared to a conventional gravel based filter layer (case 1A) with regard to all impact category indicators investigated. For all indicators the filter with geosynthetics causes less than 25 % of the impacts of a conventional gravel based filter. The non-renewable cumulative energy demand of the construction of 1 square meter filter with a life time of 30 years is 131 MJ-eq in case 1A and 19 MJ-eq in case 1B. The cumulative greenhouse gas emissions amount to 7.8 kg CO_2-eq/m^2 in case 1A and 0.81 kg CO_2-eq/m^2 in case 1B.

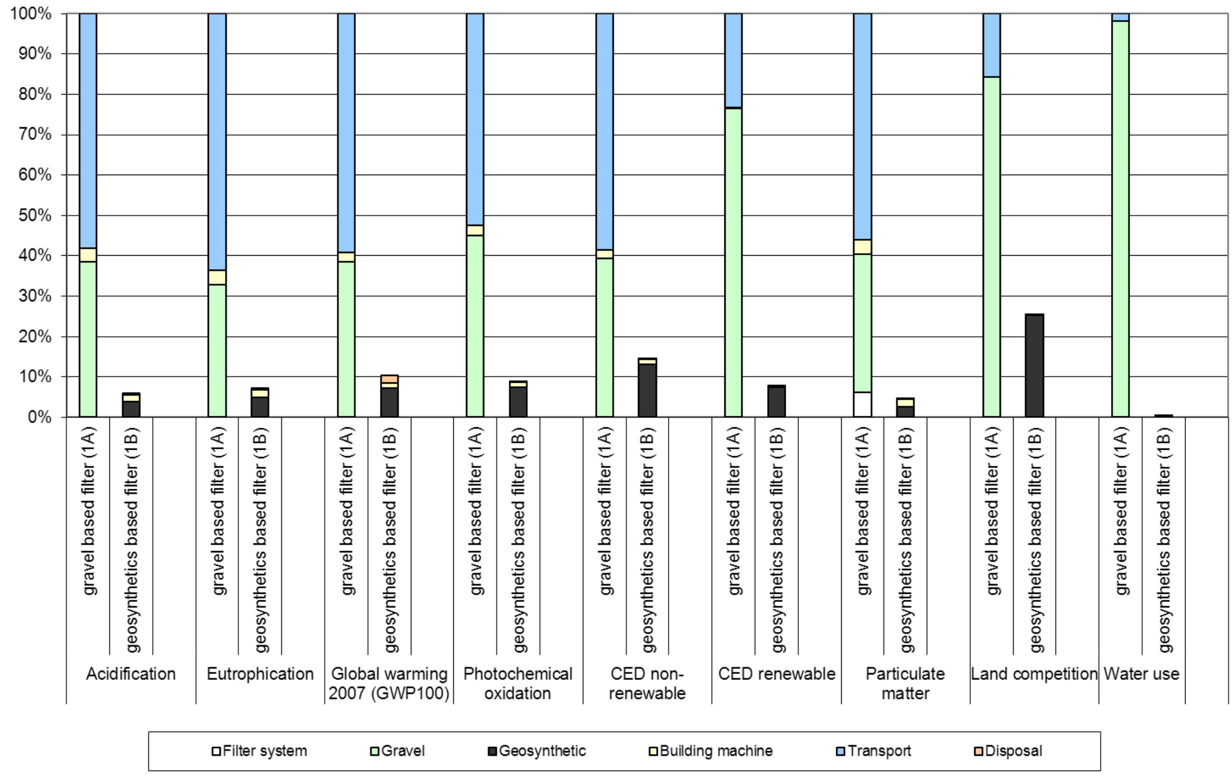

Fig. S. 1: Environmental impacts of the life cycle of 1 m² filter for the cases 1A and 1B. For each indicator, the case with higher environmental impacts is scaled to 100 %.

A conventional road (case 2A) causes higher impacts compared to a road reinforced with geosynthetics (case 2B) with regard to all impact category indicators. The higher impacts of case 2A are caused by the emissions and the resource consumption related to the production and transportation of the additional amount of gravel required. With regard to global warming, the road construction with a cement/lime stabilised foundation (case 2C) causes higher impacts compared to cases 2A and 2B mainly because of the geogenic CO_2 emissions from the calcination process in the clinker and quick lime production. With regard to land use, the impacts of all three alternatives are more or less equal, with a maximal deviation in case 2C, using only 2.2 % less land than case 2A. Case 2C causes lower eutrophying and particulate matter emissions and requires less water compared to cases 2A and 2B.

The non-renewable cumulative energy demand of the construction and disposal of 1 meter stabilised road with a width of 12 meters and a life time of 30 years is 25’200 MJ-eq in case 2A, 23’900 MJ-eq in case 2B and 24’400 MJ-eq in case 2C. The cumulative greenhouse gas emissions amount to 0.73 t CO_2-eq/m^2 in case 2A, to 0.65 t CO_2-eq/m^2 in case 2B and to 0.95 t CO_2-eq/m^2 in case 2C. Correspondingly, the cumulative greenhouse gas emissions of 1 km stabilised road are 730 t CO_2-eq in case 2A, 650 t CO_2-eq in case 2B and 950 t CO_2-eq in case 2C.

The uncertainty assessment confirms that case 2B causes lower environmental impacts than case 2A with regard to all indicators. For the comparison of case 2B and case 2C the uncertainty analysis shows lower impacts for the categories CED renewable, photochemical oxidation and global warming potential for case 2B. Regarding the indicator land competition the case 2B causes higher environmental impacts than case 2C. With regard to all other indicators the uncertainty analysis reveals no clear ranking between cases 2B and 2C.

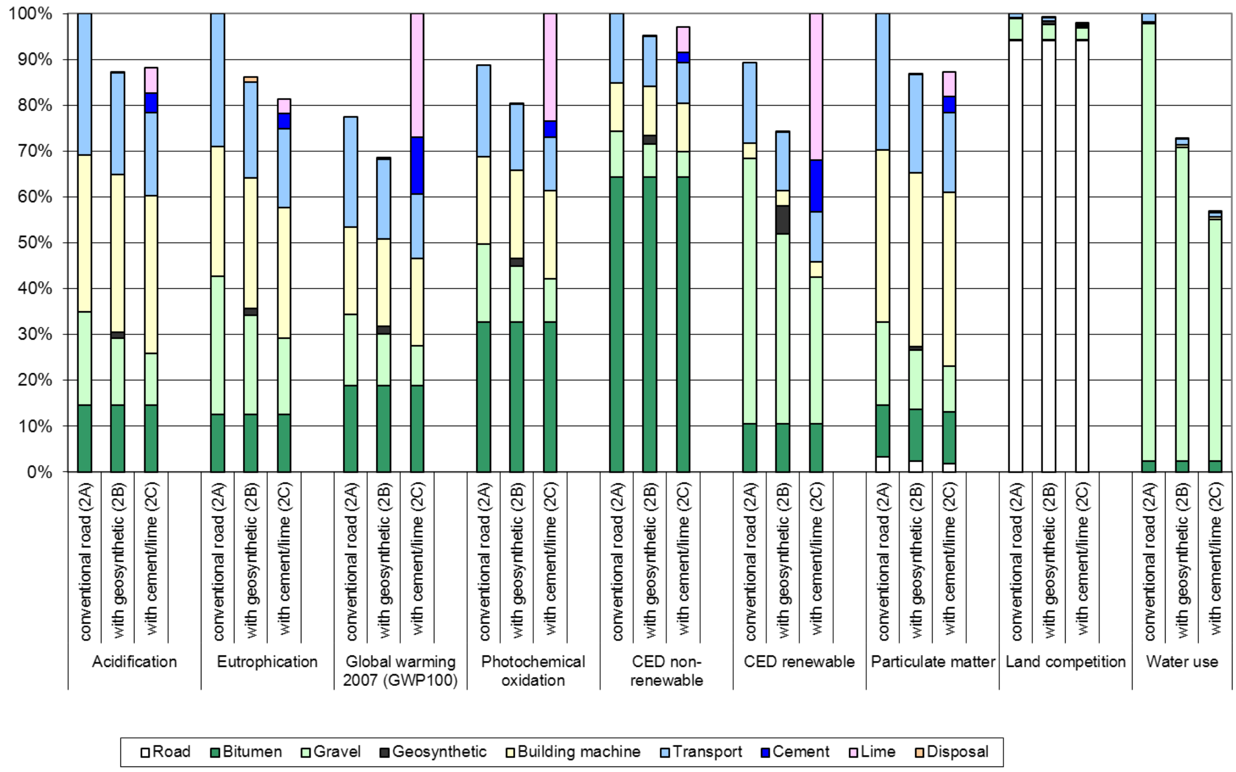

Fig. S. 2: Environmental impacts of the life cycle of 1 m road with stabilised foundation, cases 2A, 2B and 2C. For each indicator, the case with higher environmental impacts is scaled to 100 %.

Fig. S. 3 shows the sensitivity analyses for road construction reinforced with geosynthetics with soil replacement (case 2BS1) and without separation geosynthetic (case 2BS2), and for road construction with stabilised foundation using quicklime only (case 2CS1) and using cement only (case 2CS2).

Using quicklime as stabiliser causes the highest environmental impacts with regard to global warming, photochemical oxidation, CED non-renewable and CED renewable. Choosing cement as stabiliser leads to higher environmental impacts for global warming, CED renewable and water use compared to case 2B.

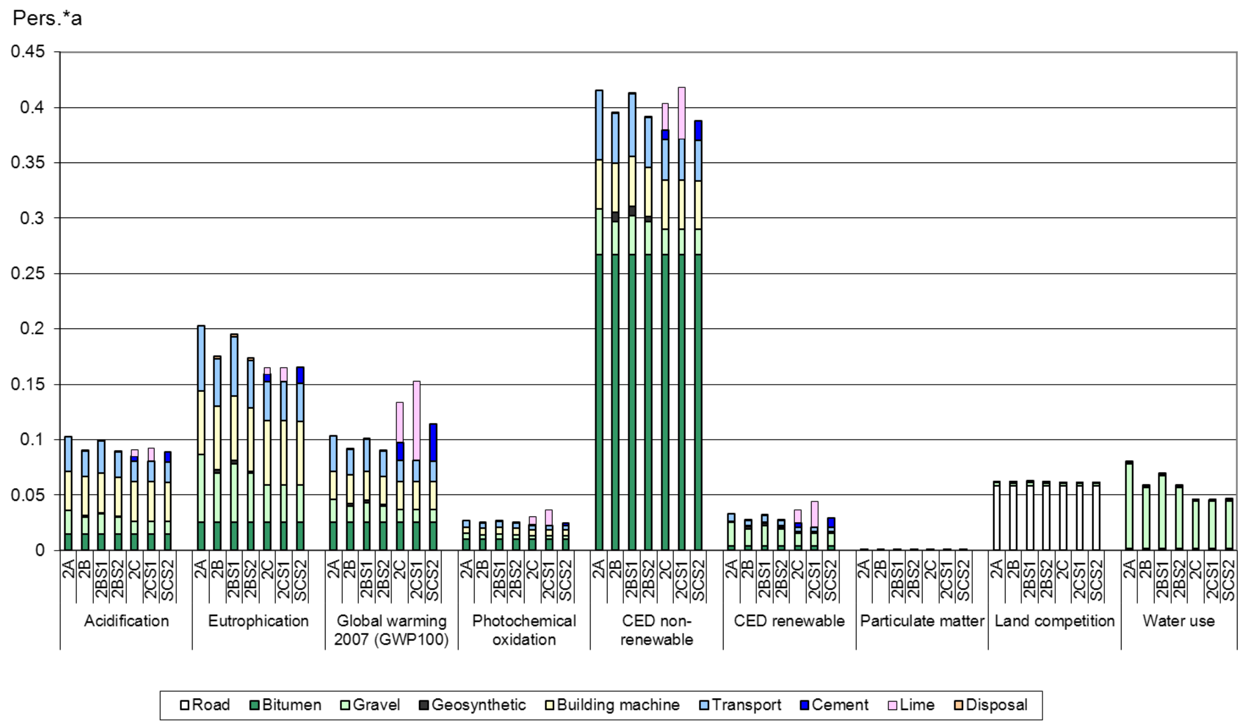

Fig. S. 3: Sensitivity analyses: environmental impacts of the life cycle of 1 m road class III, cases 2A, 2B and 2C. Case 2BS1: construction of a class III road reinforced with geosynthetics with soil replacement; case 2BS2: construction of road reinforced with geosynthetics without separation geosynthetic; case 2CS1: construction of road reinforced with quicklime stabiliser; case 2CS2: construction of road reinforced with a cement stabiliser. For each indicator, the results are normalised with the annual world impacts per capita.

A geosynthetic drainage layer (case 3B) causes lower environmental impacts compared to a gravel based drainage layer (case 3A) in all impact categories considered except land competition which is about the same in both cases. The non-renewable cumulative energy demand of the construction and disposal of 1 square meter drainage layer is 194 MJ-eq in case 3A and 86 MJ-eq in case 3B. The cumulative greenhouse gas emissions amount to 10.9 kg CO_2-eq/m^2 in case 3A and 3.6 kg CO_2-eq/m^2 in case 3B. Correspondingly, the cumulative greenhouse gas emissions of the drainage layer of a landfill with an area of 30’000 m^2 are 330 t CO_2-eq in case 3A and 110 t CO_2-eq in case 3B respectively.

The Monte Carlo Simulation reveals a probability of more than 99 % that the geosynthetic drainage layer has lower environmental impacts than the mineral drainage layer for all indicators investigated except land competition. Regarding land competition, the probability that geosynthetic drainage layer has lower environmental impacts than the mineral drainage layer is 62 %.

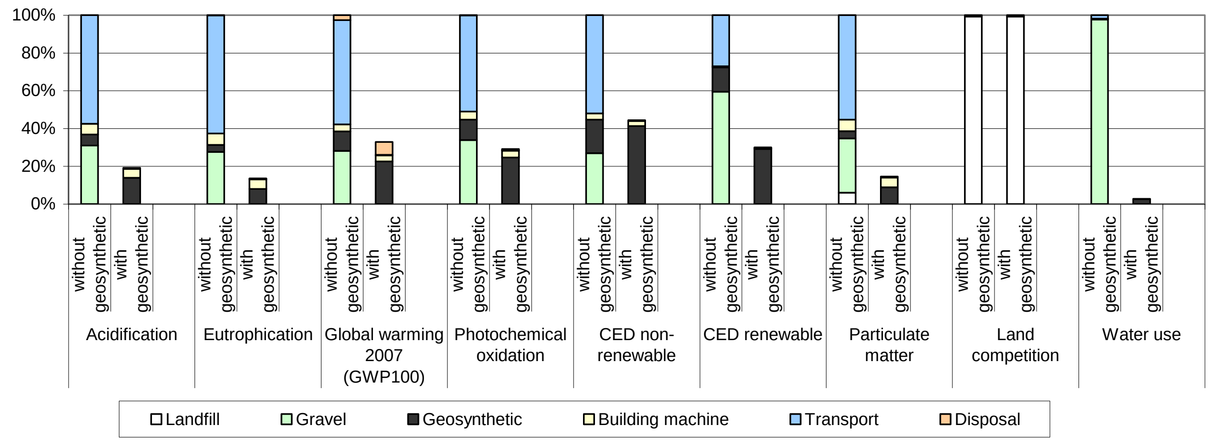

Fig. S. 4: Environmental impacts of the life cycle of 1 m² mineral drainage layer (case 3A) and a geosynthetic drainage layer (case 3B). For each indicator, the case with higher environmental impacts is scaled to 100 %.

A geosynthetic reinforced wall (case 4B) causes lower environmental impacts compared to a reinforced concrete wall (case 4A) in all impact categories considered. The non-renewable cumulative energy demand of the construction and disposal of 1 meter slope retention with a height of 3 meters is 12’700 MJ-eq in case 4A and 3’100 MJ-eq in case 4B. The cumulative greenhouse gas emissions amount to 1.3 t CO_2-eq/m in case 4A and 0.2 t CO_2-eq/m in case 4B. Correspondingly, the cumulative greenhouse gas emissions of 300 m slope retention are 400 t CO_2-eq in case 4A and 70 t CO_2-eq in case 4B respectively. The Monte Carlo simulation shows a probability of 100 % that the environmental impacts of the conventional slope retention are higher compared to the environmental impacts of the geosynthetic slope retention with regard to all indicators.

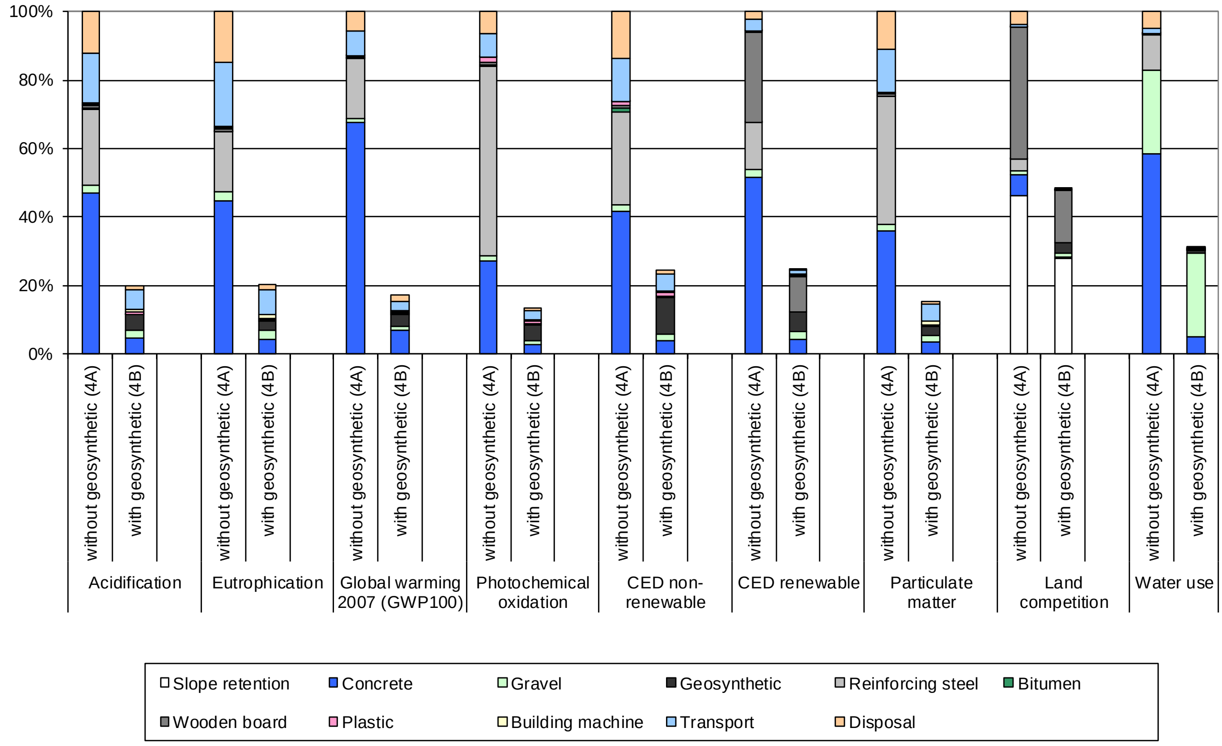

Fig. S. 5: Environmental impacts of the life cycle of 1 m slope retention, cases 4A and 4B. For each indicator, the case with higher environmental impacts is scaled to 100 %.

A sensitivity analysis regarding transportation of the materials with a Euro5 lorry instead of a fleet average lorry shows lower environmental impacts regarding those indicators and cases where the transportation of the materials has an important share in the result. This applies for the conventional separator layer in case 1, the geosynthetic stabilised layer in case 2B (see Fig. S. 3), the conventional drainage layer in case 3A and in both types of slope retention. The sequence of the environmental impacts of the cases compared does not change in any of the four cases.

Conclusions and Recommendations

A **filter layer with geosynthetics** has lower environmental impacts compared to a conventional alternative (gravel). The difference is considerable for all indicators (more than 85 %) and reliable. The difference in the environmental impacts arises mainly because the applied geosynthetic substitutes gravel, which causes considerably higher impacts when extracted and transported to the place of use. At least a layer of 8 cm of gravel must be replaced by geosynthetics used as a filter in order to cause the same or lower environmental impacts regarding all indicators.

When comparing the use of **geosynthetics in road construction** in order to reinforce the road foundation (case 2B) and the conventional road construction (case 2A), the environmental impact is reduced for all indicators when using geosynthetics. When road construction using geosynthetics (case 2B) and the road construction with cement/lime stabilised foundation (case 2C) are compared, a trade-off between the cases 2B and 2C can be observed. On the one hand, the use of a cement/lime stabiliser causes higher climate change impacts mainly because of the geogenic CO_2 emissions from the production process of cement and quicklime. On the other hand, the use of a geosynthetic stabiliser shows higher results for the environmental indicators eutrophication, water use and particulate matter because of the emissions and the resource consumption related to the production and transportation of the additional amount of gravel required. The use of quick lime only (case 2CS1) causes higher environmental impacts than the use of cement (case 2CS2) for the stabilisation of the road foundation. At least a layer of 25 cm of gravel in a conventional road must be replaced by geosynthetics used in road foundation in order to cause the same or lower environmental impacts regarding all indicators.

The **uncertainty analysis** shows that results are reliable for all indicators when comparing case 2A and 2B and that the results are stable for the indicators photochemical oxidation, global warming, land competition and CED renewable when comparing the case 2B and 2C. Regarding the other indicators the difference between the cases 2B and 2C is considerably less reliable.

The main driving forces for the difference between the geosynthetic **drainage layer in a landfill site** and the conventional gravel drainage layer is the extraction and transportation of gravel used in the conventional case. For all indicators except land competition, the impacts of the conventional drainage layer are more than twice as high as compared to the impacts from the geosynthetic drainage layer. The Monte Carlo simulations show that differences can be considered reliable and significant with regard to all indicators except land competition. Regarding the latter, the two alternatives can be considered as equivalent.

Compared to the conventional slope retention, the geosynthetic **reinforced wall** substitutes the use of concrete and reinforcing steel, which results in lower environmental impacts of between 52 % and 87 %. The uncertainty analysis shows that it is reliable that the use of geosynthetics causes lower environmental impacts compared to a conventional slope retention.

The main share of the environmental impacts of the manufacture and disposal of geosynthetic layers are caused by the raw materials and electricity consumption. However, the shares in the total environmental impacts of the four cases are small, except in case 4 where geosynthetics can have an important contribution in some indicators. The variation in environmental impacts of geosynthetics manufacture does not affect the overall results as shown with the Monte Carlo simulations. Hence the results shown in this report are valid for the products of any particular manufacturer.

Geosynthetic layers and geogrids can contribute to civil engineering constructions with significantly lower climate change impacts in all cases considered. The use of geosynthetic layers may also lead to lower environmental impacts such as acidification, eutrophication, and to lower cumulative energy demands, except for the case of foundation stabilisation (case 2), where these environmental impacts are higher compared to conventional solutions.

It is recommended to establish key parameter models for each of the four cases, which allow for an individual assessment of alternatives of any particular construction. This is particularly true for case 4, where actual situations may ask for highly specific technical solutions. In such key parameter models the main determining factors such as amount of gravel, cement, concrete or geosynthetics needed, can be entered to calculate the environmental impacts of the construction alternatives at issue.

Evaluation of the timeliness of the comparative life cycle assessment published in 2011

The timeliness of the comparative life cycle assessment of geosynthetics versus conventional construction materials was evaluated in 2018 in order to provide a decision basis on whether the study needs to be updated in full or in part. The EAGM commissioned treeze Ltd. to assess the following questions:

1. Are the design criteria and the construction requirements of the four cases still valid?
2. Are the manufacturing data for geosynthetic materials still appropriate?
3. Are there significant changes due to an update of the underlying LCI data?

The scope of the evaluation of the timeliness comprises EAGM members supplying the European market for geosynthetic materials.

The **appropriateness of the four cases** (question 1) was analysed by Henning Ehrenberg on behalf of the EAGM. The design criteria and construction requirements for filter layers, foundation stabilisations, landfills and slope retentions with geosynthetics and conventional construction materials have remained unchanged since the comparative life cycle assessment was carried out in 2011. The four cases are therefore still appropriate and the bills of materials and construction efforts do not need to be updated.

The **appropriateness of the data for the manufacture of geosynthetic materials** (question 2) was assessed by conducting a survey among EAGM members. The manufacturers were asked about potential changes in the product portfolio, the product design, the production processes and the production plants. The collection of foreground data for the manufacture of geosynthetic materials (e.g. use of raw materials, energy demand, pollutant emissions) was not part of this survey. 21 companies were members of the EAGM at the time the survey was carried out. Between 2011 and 2018, four manufacturers newly joined the EAGM, while four former members left the EAGM. 14 manufacturers of geosynthetic materials took part in the survey, including two companies who joined the EAGM since 2011.

The response rate was fair or good for the four cases. In each case, there were a few manufacturers who did not provide data for the comparative life cycle assessment in 2011. The companies who joined the EAGM since 2011 manufacture geosynthetics for all cases considered.

Most of the data providers in 2011 confirmed that they continue to produce geosynthetic materials for the respective cases, only a few companies declared to have stopped production. Very few EAGM members reported to have put new production plants into operation or to use more energy efficient burners. The product design and the production process are unchanged according to all responding manufacturers.

The data gathered for the comparative life cycle assessment carried out in 2011 represent a total of more than 20 production plants for the four cases. The few additional production plants used to manufacture geosynthetic materials and the optimisation in the production process of one manufacturer are expected to cause only minor changes in the environmental impacts of geosynthetic material production. The manufacturing data are therefore still considered as appropriate.

The **changes due to an update of the underlying LCI data** (question 3) were assessed using the case 2 (foundation stabilisation) as an example. The KBOB LCI data DQRv2:2016 (KBOB et al. 2016) was used for these analyses. It is an extensively updated version of ecoinvent data v2.2 (ecoinvent Centre 2010), which was used in the comparative life cycle assessment carried out in 2011. Updated life cycle inventories of freight transports by lorry and of the operation of building machines (Stolz et al. 2016) were embedded in the KBOB LCI data DQRv2:2016. The foreground life cycle inventories of the construction of foundation stabilisations with and without geosynthetic materials were not changed and the impact category indicators were the same as in the 2011 study. The environmental impacts of a conventional road (case 2A), a road reinforced with geosynthetics (case 2B) and a road stabilised with cement / lime (case 2A) as quantified with ecoinvent data v2.2 and KBOB LCI data DQRv2:2016 are shown in Tab. S. 2.

Tab. S. 2: Environmental impacts of the life cycle of 1 m road with stabilised foundation, cases 2A, 2B and 2C. The results of the 2011 study based on ecoinvent data v2.2 are compared to the results based on the updated background data of KBOB LCI data DQRv2:2016. The foreground life cycle inventories were not changed.

Impact category	Unit	ecoinvent data v2.2			KBOB LCI Data DQRv2:2016		
		Conventional Road (2A)	With Geosynthetic (2B)	With Cement/Lime (2C)	Conventional Road (2A)	With Geosynthetic (2B)	With Cement/Lime (2C)
Acidification	kg SO_2eq	3.99	3.48	3.52	3.39	3.09	3.30
Eutrophication	kg PO_4^{3-}eq	1.12	0.962	0.907	0.767	0.675	0.653
Global warming 2007 (GWP100)	kg CO_2eq	734	651	949	704	625	921
Photochemical oxidation	kg C_2H_4	0.163	0.147	0.183	0.195	0.179	0.218
CED non-renewable	MJ-eq	25'156	23'897	24'424	24'927	23'739	24'292
CED renewable	MJ-eq	234	195	262	279	234	307
Particulate matter	kg PM_{10}eq	1.94	1.68	1.69	1.21	1.06	1.13
Land competition	m^2a	383	379	374	383	380	375
Water use	m^3	50.2	36.5	29.0	50.1	36.4	28.9

The use of KBOB LCI data DQRv2:2016 leads to higher environmental impacts according to the indicators photochemical oxidation and CED renewable for each alternative of case 2. On the other hand, the environmental impacts are lower in the impact categories acidification, eutrophication and particulate matter when using KBOB LCI data DQRv2:2016 compared to ecoinvent data v2.2. The change due to an update of the underlying life cycle inventory data is insignificant (<5 %) for the impact categories global warming, CED non-renewable, land competition and water use.

The magnitude of change is similar for the cases 2A, 2B and 2C. Hence, the order of alternatives does not change irrespective of the impact category indicator considered. The relative magnitude of the environmental impacts of the three alternatives may however change for some indicators. For instance, the difference between the road reinforced with geosynthetics (case 2B) and the road stabilised with cement / lime (case 2C) becomes more pronounced in the impact category particulate matter.

The contributions of the most important materials and processes to the environmental impacts of the three alternatives of roads with stabilised foundation based on KBOB LCI data DQRv2:2016 are shown in Fig. S. 6 (see Fig. S. 2 for the results with ecoinvent v2.2 background data). The use of updated background data leads to a higher contribution of bitumen for most impact category indicators, which is due to a different crude oil mix used by refineries with higher shares of Russian, Kazakh and Azerbaijani crude oil. The updated life cycle inventories of freight transports by lorry and of the operation of building machines result in lower contributions of these processes to the environmental impact indicators acidification, eutrophication and particulate matter. This is mainly due to reduced NO_x emissions of lorries and building machines with more stringent emission standards. The contribution of the geosynthetic material in case 2B remains small for all impact categories analysed.

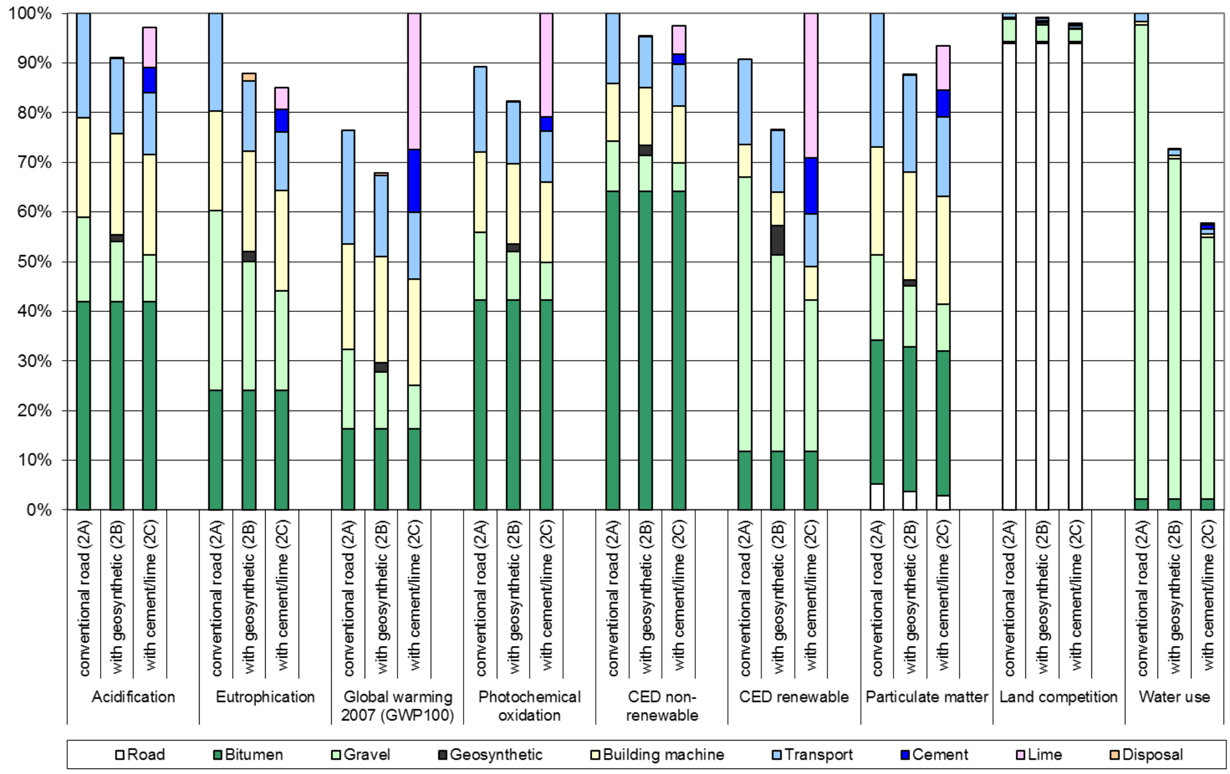

Fig. S. 6: **Environmental impacts of the life cycle of 1 m road with stabilised foundation, cases 2A, 2B and 2C, as calculated using the updated background data of KBOB LCI data DQRv2:2016. For each indicator, the case with higher environmental impacts is scaled to 100 %.**

The sensitivity analyses for the alternatives 2BS1, 2BS2, 2CS1 and 2CS2 (see Fig. S. 6above) were also performed using the updated background data of KBOB LCI data DQRv2:2016 (Fig. S. 7). For most impact category indicators, the update of the underlying LCI data leads to changes in the relative magnitude of the impacts and the most important contributors but does not affect the order of the alternatives. However, the order changes according to the indicators acidification and particulate matter. The case 2CS1 (road reinforced with quicklime stabilizer) causes the highest acidification impacts and the second-highest particulate matter impacts when using KBOB LCI data DQRv2:2016. The environmental impacts of the case 2CS2 (road reinforced with cement stabilizer) are higher compared to impacts caused by the case 2B according to the indicators acidification and particulate matter.

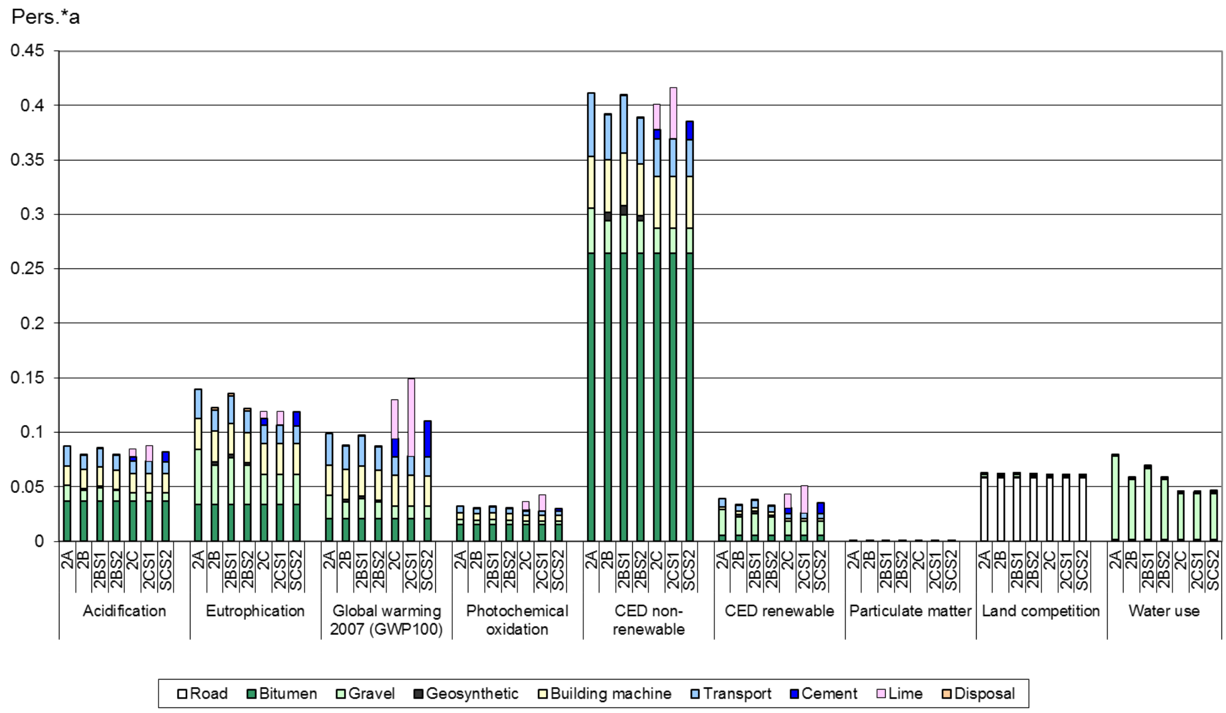

Fig. S. 7: Environmental impacts of the life cycle of 1 m road class III, cases 2A, 2B and 2C and for the sensitivity analyses (cases 2BS1, 2BS2, 2CS1 and 2CS2) as calculated using the updated background data of KBOB LCI data DQRv2:2016. For each indicator, the results are normalised with the annual world impacts per capita.

In summary, the use of the updated background data of KBOB LCI data DQRv2:2016 mainly affects the absolute magnitude of the environmental impacts but has no influence on the order of the alternatives 2A, 2B and 2C. The contributions of the most important materials and processes to the total environmental impacts change, whereby the share of the manufacture of geosynthetic materials remains small. The effect of new manufacturers or new production plants on the overall results is expected to be insignificant since the environmental impacts of geosynthetics manufacture are partly caused by the supply of raw materials. The background data has therefore the highest potential to change the results of the comparative life cycle assessment of geosynthetics versus conventional construction materials.

The report and its main conclusions of the study carried out in 2011 are found to be still valid.

Abbreviations

CED	Cumulative Energy Demand
EAGM	European Association of Geosynthetic product Manufacturers
FSS	Frost Sensitive Soil
GWP	Global Warming Potential
IEA	International Energy Agency
LCA	Life Cycle Assessement
LCI	Life Cycle Inventory
NMVOC	Non-methane volatile organic compounds
PE	Polyethylene
PET	Polyethylene terephtalate
PP	Polypropylene