DOCUMENTATION OF LAND USE INDICATORS VALUES IN GABI 4

1 INTRODUCTION

Apart from the classical impact categories like GWP, AP, EP, POCP etc., land use as an environmental issue is widely considered to be very important and constantly gains attention in the Life Cycle Assessment (LCA) community (cp. for example LINDEIJER (2000), MILÀ I CANALS ET AL. (2007).

In the software and database system GaBi 4 land use parameters are integrated, starting with the version GaBi 4.4. The methodology behind is based on the dissertation of Martin Baitz (BAITZ 2002) and subsequent work, that was carried out at the University of Stuttgart, Chair of Building Physics (LBP), Dept. Life Cycle Engineering (GaBi; former Institute for Polymer Testing and Polymer Science) and PE International GmbH (cp. BECK, BOS, WITTSTOCK ET AL. 2010).

According to BAITZ (2002), a set of indicators has been defined to model land use aspects in LCA and incorporate them into the software. These are:

- Erosion Resistance,
- Mechanical Filtration,
- Physicochemical Filtration,
- Groundwater Replenishment,
- Biotic Production.

These land use indicators are calculated for several land intensive processes with the support of the LANCA tool (Land Use Indicator Calculation Tool) based on country-specific input data[1] and the respective land use types (cp.Table 2 - Table 8). A detailed description of the underlying methods can be found in BECK, BOS, WITTSTOCK ET AL. (2010).

The values calculated according to these methods are then integrated in the GaBi 4 database and software and aggregated over the process chain to form environmental indicators that are representative for the entire life cycle of many of the aggregated processes in the GaBi database system. Thus, land use can be considered as an additional aspect in LCA to extend its environmental impact evaluation.

[1] Country-specific input data for the tool has been derived from the ISRIC database (ISRIC WISE 2002) for the input parameters of humus content, skeletal content, declination, and effective cation exchange capacity and from MITCHELL (2003); TYN CY 1.1 data set for precipitation, summer precipitation and evapotranspiration. For the input parameter of "distance to groundwater", a default value (0.8-10m) is used.

For the calculation of indicator values, indicator qualities Q have to be calculated for the state and land use types of the land before transformation (t_1) during use (t_2 and t_3), and after regeneration of the land (t_4) (cp. BECK, BOS, WITTSTOCK ET AL. 2010). At this stage it is assumed, that the occupation phase is a static situation; consequently, for all processes calculated, t_2 and t_3 have the same land use type. For each indicator, occupation and transformation in general are calculated as follows:

Occupation indicator value = $(Q(t_{4,\ ref})-Q(t_{2,3}))$*area used*time of occupation

Transformation indictor value = $(Q(t_4)-Q(t_1))$*area used

The resulting units of qualities, transformation and occupation indicator values as used in GaBi are shown in Table 1**.**

Table 1: Indicator units

Indicator	Quality unit	Transformation indicator unit	Occupation indicator unit
Erosion Resistance	[kg/(ha*a)]	[kg/a]	[kg]
Mechanical Filtration	[cm/d]	[cm*m²/d]	[cm*m²]
Physicochemical Filtration	[cmol/kg_{soil}]	[(cmol*m²)/ kg_{soil}]	[(cmol*m²*a)/ kg_{soil}]
Groundwater Replenishment	[mm/a]	[(mm*m²)/a]	[mm*m²]
Biotic Production	[kg[2]/(m²*a)]	[kg/a]	[kg]

Positive occupation indicator values can be interpreted as follows:

- Erosion Resistance (expressed by kg of erosion): kg of soil eroded in addition to naturally occurring soil erosion due to the effects caused by the production of one functional unit.

- Mechanical Filtration: amount of water that could not be filtered due to the effects caused by the production of one functional unit.

[2] kg dry mass

- Physicochemical Filtration: amount of cations that could not be fixed to the soil due to the effects caused by the production of one functional unit.

- Groundwater Replenishment: amount of groundwater, which could not be replenished due to the effects caused by the production of one functional unit.

- Biotic Production: amount of biomass not produced due to the effects caused by the production of one functional unit.

Positive transformation indicator values (permanent impacts) can be interpreted as follows:

- Erosion Resistance: kg of soil eroded in addition to naturally occurring soil erosion per year in the time following the regarded land use on the used land due to the permanent transformation impacts caused by the production of one functional unit.

- Mechanical Filtration: amount of water that cannot be filtered in the time following the regarded land use per day on the used land due to the permanent transformation impacts caused by the production of one functional unit.

- Physicochemical Filtration: amount of cations that cannot be fixed to the soil in the time following the regarded land use on the used land, due to the permanent transformation impacts caused by the production of one functional unit.

- Groundwater Replenishment: amount of groundwater, which cannot be replenished in the time following the regarded land use per year on the used land, due to the permanent transformation impacts caused by the production of one functional unit.

- Biotic Production: amount of biomass that is not produced in the time following the regarded land use per year on the used land due to the permanent transformation impacts caused by the production of one functional unit.

Negative indicator values show the respective positive impacts.

According to BAITZ (2002), the reference situation t_{ref} is assumed to be the same as the situation t_4.

2 GABI 4 DOCUMENTATION

For the following process groups, land use indicator values have been implemented into GaBi 4 and are documented in this report:

- Agricultural processes
- Bauxite
- Copper
- Hard coal
- Iron Ore
- Lignite
- Ore

Table 2 - Table 8 show for the different countries and process types the land use types regarding t_1-t_4, respectively t_{ref} . The land use types for t_1 were chosen in discussions with experts according to the predominant land use type in the area where the land occupation takes place out of geographical maps. The situations t_4 respectively t_{ref} were also chosen in expert discussions on the basis of geographical maps showing the natural vegetation in the specific area. For example it was agreed, that a primary rain forest used as a mining area cannot become a primary rain forest after the use phase again. It was said that the area is strongly disturbed and can host only secondary vegetation types.

For the agricultural processes, no transformation indicator values are calculated. This is due to the fact that the farmland is used a long time for farming in contrary to a mining area. Farmland can be “used” for hundreds of years. That means it was often farmland before the specific use and afterwards again. As a further research need there has to be found an allocation method that addresses this issue.

Table 2: Land use types for agricultural processes

Country	t_1	t_2, t_3	t_4, t_{ref}
Brazil	Farmland (no complete surface vegetation)	Farmland (no complete surface vegetation)	Tropical savannah
Canada	Farmland (no complete surface vegetation	Farmland (no complete surface vegetation)	Wood: Coniferous woodlands
France	Farmland (no complete surface vegetation)	Farmland (no complete surface vegetation)	Wood: Mixed tree woodlands
Germany	Farmland (no complete	Farmland (no complete	Wood: Mixed tree

Country	t_1	t_2, t_3	t_4, t_{ref}
	surface vegetation)	surface vegetation)	woodlands
Malaysia	Wood: (Sub-) tropical Rainforest	Farmland (no complete surface vegetation)	Wood: (Sub-) tropical Rainforest
Thailand	Wood: (Sub-) tropical Rainforest	Farmland (no complete surface vegetation)	Wood: (Sub-) tropical Rainforest
United States of America	Farmland (no complete surface vegetation	Farmland (no complete surface vegetation)	Wood: Mixed tree woodlands

NOTE: **"Wood" in this document is defined to be natural, non processed and naturally grown woodland "Forest" in this document is defined to be artificially planted wood deemed to be processed artificially**

Table 3: Land use types for Bauxite extraction sites

Country	t_1	t_2, t_3	t_4, t_{ref}
Australia	Wood: Deciduous woodlands, unspecific	Mining area	Forest steppe
Brazil	Wood: (Sub-) tropical Rainforest	Mining area	Fallow ground (no surface vegetation)

Table 4: Land use types for Copper extraction sites

Country	t_1	t_2, t_3	t_4, t_{ref}
Argentina	Temperate savannah	Mining area	Semi-desert
Australia	Temperate savannah	Mining area	Semi-desert
Chile	Semi-desert	Mining area	Semi-desert
Indonesia	Wood: (Sub-) tropical Rainforest	Mining area	Fallow ground (no surface vegetation)
Sweden	Forest: Coniferous forest	Mining area	Tundra

Table 5: Land use types for Hard coal extraction sites

Country	t_1	t_2, t_3	t_4, t_{ref}

Country	t_1	t_2, t_3	t_4, t_{ref}
Australia	Wood: Deciduous woodlands, unspecific	Mining area	Forest steppe
Bosnia	Moorland, lawn	Mining area	Moorland, lawn
Brazil	Wood: (Sub-) tropical Rainforest	Mining area	Fallow ground (no surface vegetation)
Canada	Wood: Coniferous woodlands	Mining area	Moorland, lawn
Chile	Grassland, meadow	Mining area	Moorland, lawn
China	Grassland, meadow	Mining area	Fallow ground (no surface vegetation)
Colombia	Wood: (Sub-) tropical Rainforest	Mining area	Fallow ground (no surface vegetation)
India	Wood: Monsoon woodlands	Mining area	Moorland, lawn
Indonesia	Wood: (Sub-) tropical Rainforest	Mining area	Fallow ground (no surface vegetation)
Italy	Forest: Mixed tree forest	Mining area	Moorland, lawn
Korea	Wood: (Sub-) tropical Rainforest	Mining area	Non continuous urban influenced area
Malaysia	Wood: (Sub-) tropical Rainforest	Mining area	Fallow ground (no surface vegetation)
Mexico	Semi-desert	Mining area	Semi-desert
New Zealand	Wood: Mixed tree woodlands	Mining area	Moorland, lawn
Philippines	Wood: (Sub-) tropical Rainforest	Mining area	Fallow ground (no surface vegetation)
Russian Federation	Wood: Coniferous woodlands	Mining area	Forest: Coniferous forest
Spain	Grassland, meadow	Mining area	Moorland, lawn
South Africa	Temperate savannah	Mining area	Semi-desert
United Kingdom	Farmland (no complete surface vegetation)	Mining area	Moorland, lawn
United States of America	Wood: Deciduous	Mining area	Moorland, lawn

Country	t_1	t_2, t_3	t_4, t_{ref}
	woodlands, unspecific		
Venezuela	Wood: (Sub-) tropical Rainforest	Mining area	Fallow ground (no surface vegetation)
Viet Nam	Wood: (Sub-) tropical Rainforest	Mining area	Fallow ground (no surface vegetation)

Table 6: Land use types for Iron ore extraction sites

Country	t_1	t_2, t_3	t_4, t_{ref}
Australia	Semi-desert	Mining area	Semi-desert
Brazil	Wood: (Sub-) tropical Rainforest	Mining area	Fallow ground (no surface vegetation)
Canada	Wood: Coniferous woodlands	Mining area	Tundra

Table 7: Land use types for Lignite extraction sites

Country	t_1	t_2, t_3	t_4, t_{ref}
Austria	Forest: Coniferous forest	Mining area	Moorland, lawn
Australia	Wood: Deciduous woodlands, unspecific	Mining area	Forest steppe
Bosnia	Moorland, lawn	Mining area	Moorland, lawn
Bulgaria	Forest: Coniferous forest	Mining area	Moorland, lawn
Canada	Farmland (no complete surface vegetation)	Mining area	Moorland, lawn
Czech Republic	Farmland (no complete surface vegetation)	Mining area	Moorland, lawn
France	Forest: Coniferous forest	Mining area	Moorland, lawn
Germany: Lausitz	Forest: Coniferous forest	Mining area	Moorland, lawn
Germany: Middle-Germany	Farmland (no complete surface vegetation)	Mining area	Moorland, lawn
Germany: Rhineland	Farmland (no complete	Mining area	Moorland, lawn

Country	t_1	t_2, t_3	t_4, t_{ref}
	surface vegetation)		
Greece	Forest steppe	Mining area	Semi-desert
Hungary	Forest: Coniferous forest	Mining area	Moorland, lawn
India	Wood: Monsoon woodlands	Mining area	Moorland, lawn
Macedonia	Moorland, lawn	Mining area	Moorland, lawn
Malaysia	Wood: (Sub-) tropical Rainforest	Mining area	Fallow ground (no surface vegetation)
Poland	Forest: Coniferous forest	Mining area	Moorland, lawn
Romania	Permanent crops (field, little surface vegetation)	Mining area	Moorland, lawn
Russian Federation	Permanent crops (field, little surface vegetation)	Mining area	Moorland, lawn
Slovakia	Moorland, lawn	Mining area	Moorland, lawn
Slovenia	Moorland, lawn	Mining area	Moorland, lawn
Spain	Grassland, meadow	Mining area	Moorland, lawn
Thailand	Wood: Monsoon woodlands	Mining area	Fallow ground (no surface vegetation)
Turkey	Forest steppe	Mining area	Semi-desert
United States of America	Wood: Deciduous woodlands, unspecific	Mining area	Moorland, lawn
Yugoslavia	Moorland, lawn	Mining area	Moorland, lawn

Table 8: Land use types for Ore extraction sites

Country	Ore	t_1	t_2, t_3	t_4, t_{ref}
Australia	ZnPbCd-ore	Temperate savannah	Mining area	Semi-desert
Australia	Titanium-ore, sand basis, TiO_2 50%	Temperate savannah	Mining area	Semi-desert
Australia	Titanium-ore	Temperate savannah	Mining area	Semi-desert
Australia	Zirconium sand	Temperate savannah	Mining area	Semi-desert

Country	Ore	t_1	t_2, t_3	t_4, t_{ref}
Brazil	Chromium ore	Wood: (Sub-) tropical Rainforest	Mining area	Fallow ground (no surface vegetation)
Canada	Nickel ore	Wood: Coniferous woodlands	Mining area	Tundra
Canada	Zn/Cu-ore	Wood: Coniferous woodlands	Mining area	Tundra
Chile	Copper-molybdenum ore	Semi-desert	Mining area	Semi-desert
China	Dolomite $CaMg[CO_3]_2$	Grassland, meadow	Mining area	Fallow ground (no surface vegetation)
China	Rare-earth metals - iron	Grassland, meadow	Mining area	Fallow ground (no surface vegetation)
Germany	Colemanite-ore	Farmland (no complete surface vegetation)	Mining area	Moorland, lawn
Germany	Natural Aggregate/ Coarse-gravel extraction	Farmland (no complete surface vegetation)	Mining area	Moorland, lawn
Germany	Quartz sand (silica sand)	Farmland (no complete surface vegetation)	Mining area	Moorland, lawn
Indonesia	Tin ore	Wood: (Sub-) tropical Rainforest	Mining area	Fallow ground (no surface vegetation)
Norway	Quartz sand (silica sand)	Forest: Coniferous forest	Mining area	Tundra
South Africa	Antimony / gold	Temperate savannah	Mining area	Semi-desert
South Africa	Manganese ore	Temperate savannah	Mining area	Semi-desert
South Africa	Silicon dioxide	Temperate savannah	Mining area	Semi-desert
Sweden	Lead-zinc ore	Forest: Coniferous forest	Mining area	Tundra
United States of America	Molybdenum	Wood: Deciduous woodlands, unspecific	Mining area	Moorland, lawn

Country	Ore	t_1	t_2, t_3	t_4, t_{ref}
United States of America	Phosphate rock mine	Wood: Deciduous woodlands, unspecific	Mining area	Moorland, lawn
United States of America	Rare-earth metals	Wood: Deciduous woodlands, unspecific	Mining area	Moorland, lawn

Table 9 to Table 13 show the respective land use productivity in m²/kg product in the different countries as well as the data sources the values are gathered from. The input for the agricultural processes is calculated using the GaBi models for the respective crops. There, the crop output per hectare is given and therefore the used m² per kg crop can be calculated.

Table 9: Land use productivity Agriculture

Country	Crop	Land use [m^2/kg crop]	Reference
Brazil	Sisal	2,37E-01	PE INTERNATIONAL (2007)
Canada	Canola	6,06E+00	PE INTERNATIONAL (2007)
France	Flax	1,46E+00	PE INTERNATIONAL (2007)
Germany	Hemp seed	2,50E+00	PE INTERNATIONAL (2007)
Germany	Hemp straw	8,00E-01	PE INTERNATIONAL (2007)
Germany	Winter rapeseed	2,50E+00	PE INTERNATIONAL (2007)
Germany	Winter wheat, corn	1,08E+00	PE INTERNATIONAL (2007)
Germany	Winter wheat straw	5,54E-02	PE INTERNATIONAL (2007)
Malaysia	Oil palm-plantation	5,09E-01	PE INTERNATIONAL (2007)
Thailand	Natural Rubber plantation(latex)perennial	2,90E+00	PE INTERNATIONAL (2007)

Country	Crop	Land use [m²/kg crop]	Reference
Thailand	Natural Rubber plantation(seed) perennial	8,06E-01	PE INTERNATIONAL (2007)
United States of America	Corn	8,50E-01	PE INTERNATIONAL (2007)
United States of America	Soja	4,05E+00	PE INTERNATIONAL (2007)

Table 10: Land use productivity Bauxite

Country	Product	Land use [m²/kg bauxite]	Reference
Australia	Bauxite	1,85E-04	MORI (1998)
Brazil	Bauxite	1,30E-04	MORI (1998)

The values for the land use in m²/kg for copper were taken from the indicated sources. Additionally they are multiplied with the respective metal contents of the different kinds of copper. The copper content varies depending on the location of the mine.

Table 11: Land use productivity Copper

Country	Product	Land use [m²/kg copper]	Reference
Argentina	Copper	1,36E-02	BILLITON (2006A), BILLITON (2007A), XSTRATA (2005), XSTRATA (2007)
Australia	Copper	1,36E-02	BILLITON (2006A), BILLITON (2007A), XSTRATA (2005), XSTRATA (2007)
Chile	Copper	1,36E-02	BILLITON (2006A), BILLITON (2007A),

Country	Product	Land use [m²/kg copper]	Reference
			XSTRATA (2005), XSTRATA (2007)
Indonesia	Copper	1,46E-02	BILLITON (2006A), BILLITON (2007A), XSTRATA (2005), XSTRATA (2007)
Sweden	Copper	1,21E-02	BILLITON (2006A), BILLITON (2007A), XSTRATA (2005), XSTRATA (2007)

Table 12: Land use productivity Hard Coal

Country	Product	Land use [m²/kg hard coal]	Reference
Australia	Hard Coal	1,30E-04	WEYER (2001)
Bosnia	Hard Coal	1,50E-04	WEYER (2001)
Brazil	Hard Coal	1,50E-04	WEYER (2001)
Canada	Hard Coal	1,30E-04	WEYER (2001)
Chile	Hard Coal	1,50E-04	WEYER (2001)
China	Hard Coal	1,20E-04	WEYER (2001)
Colombia	Hard Coal	1,50E-04	WEYER (2001)
India	Hard Coal	1,40E-04	WEYER (2001)
Indonesia	Hard Coal	1,50E-04	WEYER (2001)
Italy	Hard Coal	1,50E-04	WEYER (2001)
Korea	Hard Coal	1,50E-04	WEYER (2001)
Malaysia	Hard Coal	1,50E-04	WEYER (2001)
Mexico	Hard Coal	1,50E-04	WEYER (2001)
New Zealand	Hard Coal	1,50E-04	WEYER (2001)
Philippines	Hard Coal	1,50E-04	WEYER (2001)

Country	Product	Land use [m²/kg hard coal]	Reference
Russian Federation	Hard Coal	1,50E-04	WEYER (2001)
Spain	Hard Coal	1,50E-04	WEYER (2001)
South Africa	Hard Coal	1,50E-04	WEYER (2001)
United Kingdom	Hard Coal	2,90E-04	WEYER (2001)
United States of America	Hard Coal	1,70E-04	WEYER (2001)
Venezuela	Hard Coal	1,50E-04	WEYER (2001)
Viet Nam	Hard Coal	1,20E-04	WEYER (2001)

Table 13: Land use productivity Iron Ore

Country	Product	Land use [m²/kg iron ore]	Reference
Australia	Iron Ore	9,21E-04	BILLITON (2006B), BILLITON (2007B) RIO TINTO (2006) RIO TINTO (2008)
Brazil	Iron Ore	9,21E-04	BILLITON (2006B), BILLITON (2007B) RIO TINTO (2006) RIO TINTO (2008)
Canada	Iron Ore	9,21E-04	BILLITON (2006B), BILLITON (2007B) RIO TINTO (2006) RIO TINTO (2008)

Table 14: Land use productivity Lignite

Country	Product	Land use [m²/kg lignite]	Reference
Austria	Lignite	1,50E-04	WEYER (2001)
Australia	Lignite	1,30E-04	WEYER (2001)

Country	Product	Land use [m²/kg lignite]	Reference
Bosnia	Lignite	1,50E-04	WEYER (2001)
Bulgaria	Lignite	1,50E-04	WEYER (2001)
Canada	Lignite	1,30E-04	WEYER (2001)
Czech Republic	Lignite	1,50E-04	WEYER (2001)
France	Lignite	1,50E-04	WEYER (2001)
Germany: Lausitz	Lignite	1,50E-04	WEYER (2001)
Germany: Middle-Germany	Lignite	1,50E-04	WEYER (2001)
Germany: Rhineland	Lignite	1,50E-04	WEYER (2001)
Greece	Lignite	1,50E-04	WEYER (2001)
Hungary	Lignite	1,50E-04	WEYER (2001)
India	Lignite	1,40E-04	WEYER (2001)
Macedonia	Lignite	1,50E-04	WEYER (2001)
Malaysia	Lignite	1,50E-04	WEYER (2001)
Poland	Lignite	1,50E-04	WEYER (2001)
Rumania	Lignite	1,50E-04	WEYER (2001)
Russian Federation	Lignite	1,50E-04	WEYER (2001)
Slovakia	Lignite	1,50E-04	WEYER (2001)
Slovenia	Lignite	1,50E-04	WEYER (2001)
Spain	Lignite	1,50E-04	WEYER (2001)
Thailand	Lignite	1,50E-04	WEYER (2001)
Turkey	Lignite	1,50E-04	WEYER (2001)
United States of America	Lignite	1,70E-04	WEYER (2001)
Yugoslavia	Lignite	1,50E-04	WEYER (2001)

The values for the land use in m²/kg for ore were taken from the indicated sources. Additionally they are multiplied with the respective metal contents of the different kinds of ore. The contents vary depending on the locations of the mines.

Table 15: Land use productivity Ore

Country	Product	Land use [m²/kg ore]	Reference
Australia	ZnPbCd-ore	4,46E-03	BILLITON (2006A), BILLITON (2007A), XSTRATA (2007), XSTRATA (2005)
Australia	Titanium-ore, sand basis, TiO_2 50%	2,43E-02	BILLITON (2006A), BILLITON (2007A), XSTRATA (2007), XSTRATA (2005)
Australia	Titanium-ore	4,62E-02	BILLITON (2006A), BILLITON (2007A), XSTRATA (2007), XSTRATA (2005)
Australia	Zirconium sand	4,05E-02	BILLITON (2006A), BILLITON (2007A), XSTRATA (2007), XSTRATA (2005)
Brazil	Chromium ore	2,14E-02	BILLITON (2006A), BILLITON (2007A), XSTRATA (2007), XSTRATA (2005)
Canada	Nickel ore	3,89E-03	BILLITON (2006A), BILLITON (2007A), XSTRATA (2007), XSTRATA (2005)
Canada	Zn/Cu-ore	3,24E-03	BILLITON (2006A), BILLITON (2007A), XSTRATA (2007), XSTRATA (2005)
Chile	Copper- molybdenum ore	1,60E-02	BILLITON (2006A), BILLITON (2007A), XSTRATA (2007),

Country	Product	Land use [m^2/kg ore]	Reference
			XSTRATA (2005)
Chile	Copper ore	1,55E-02	BILLITON (2006A), BILLITON (2007A), XSTRATA (2007), XSTRATA (2005)
China	Dolomite $CaMg[CO_3]_2$	1,58E-04	BILLITON (2006A), BILLITON (2007A), XSTRATA (2007), XSTRATA (2005)
China	Rare-earth metals - iron	1,90E-02	BILLITON (2006A), BILLITON (2007A), XSTRATA (2007), XSTRATA (2005)
Germany	Colemanite-ore	1,58E-04	BILLITON (2006A), BILLITON (2007A), XSTRATA (2007), XSTRATA (2005)
Germany	Natural Aggregate/ Coarse-gravel extraction	1,58E-04	BILLITON (2006A), BILLITON (2007A), XSTRATA (2007), XSTRATA (2005)
Germany	Quartz sand (silica sand)	1,58E-04	BILLITON (2006A), BILLITON (2007A), XSTRATA (2007), XSTRATA (2005)
Indonesia	Tin ore	3,50E-02	BILLITON (2006A), BILLITON (2007A), XSTRATA (2007), XSTRATA (2005)
Norway	Quartz sand (silica sand)	1,58E-04	BILLITON (2006A), BILLITON (2007A), XSTRATA (2007), XSTRATA (2005)

Country	Product	Land use [m²/kg ore]	Reference
South Africa	Antimony / gold	1,85E-02	BILLITON (2006A), BILLITON (2007A), XSTRATA (2007), XSTRATA (2005)
South Africa	Manganese ore	2,09E-02	BILLITON (2006A), BILLITON (2007A), XSTRATA (2007), XSTRATA (2005)
South Africa	Silicon dioxide	1,58E-04	BILLITON (2006A), BILLITON (2007A), XSTRATA (2007), XSTRATA (2005)
Sweden	Lead-zinc ore	3,69E-02	BILLITON (2006A), BILLITON (2007A), XSTRATA (2007), XSTRATA (2005)
United States of America	Molybdenum	1,02E-04	BILLITON (2006A), BILLITON (2007A), XSTRATA (2007), XSTRATA (2005)
United States of America	Phosphate rock mine	1,21E-02	BILLITON (2006A), BILLITON (2007A), XSTRATA (2007), XSTRATA (2005)
United States of America	Rare-earth metals	4,13E-03	BILLITON (2006A), BILLITON (2007A), XSTRATA (2007), XSTRATA (2005)

3 EXAMPLE

In the example, results and respective interpretation approaches are presented for Erosion Resistance (Transformation) and Biotic Production (Occupation). Indicator values are shown for the extraction of 1 t of lignite in Spain and 1 t of lignite in Malaysia. The respective indicator values, scaled to 1 kg, can be found in the GaBi 4 database.

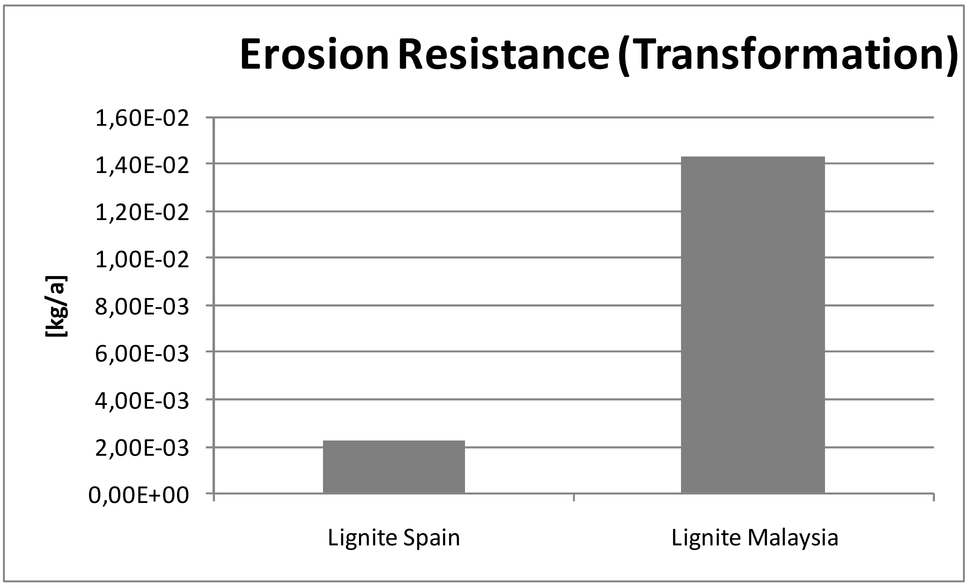

Figure 1: Erosion Resistance transformation indicator values for the extraction of 1 t of lignite in Spain and Malaysia

Transformation examines the permanent impacts caused by a land use. It is calculated with the following formula:

$(Q(t_4)-Q(t_1))$*area used.

Figure 1 shows the Erosion Resistance transformation indicator values for the extraction of 1 t of lignite in Spain compared to the indicator values for the extraction of 1 t lignite in Malaysia. Both values are positive, which means there is a negative impact on the environment. In Spain for 1 t of lignite an amount of 0.0023 kg soil is additionally eroded to the naturally occurring soil erosion per year in the time following the regarded land use on the used land due to the permanent impacts of the transformation. In Malaysia this amount sums up to 0.0143 kg. The reason for the discrepancy between the lignite extraction impacts in Spain and Malaysia is due to the different land qualities for the land use types in the situation t_1 and t_4. In Spain the land use type for t_1 is grassland, for t_4 it is a moor[3] landscape that represents fallow land with some vegetation. The quality differences of the two situations are not as grave as for Malaysia: There, the land use type for t_1 is (sub-) tropical

[3] not representing hill or raised moors, but depleted land.

rainforest and for t_4 it is fallow ground, representing a wasteland with very few vegetation. Concerning impact factors for erosion, rainforest does have a very high land quality, wasteland a lower one. Therefore, the difference between the two qualities is bigger than for the extraction of lignite in Spain.

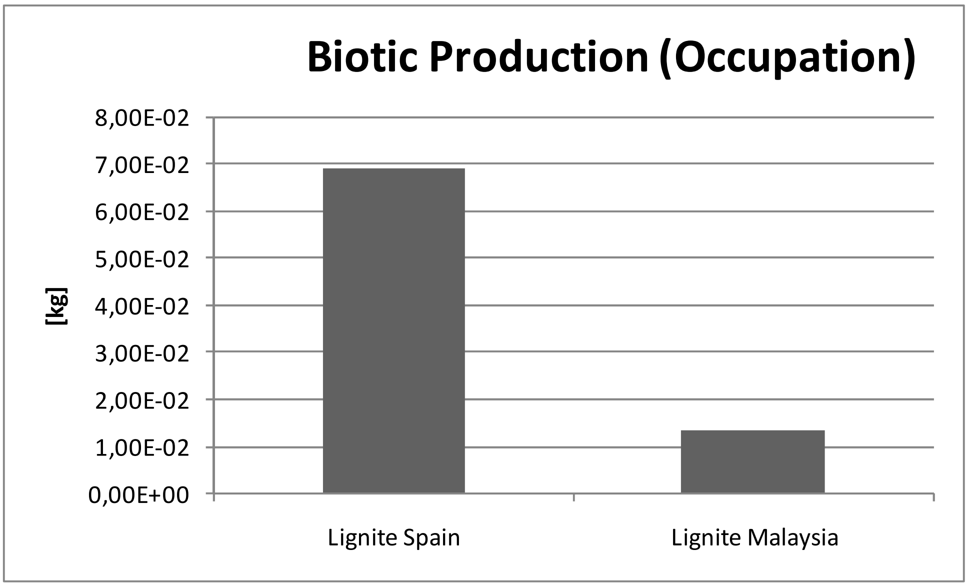

Figure 2: Biotic Production occupation indicator values for the extraction of 1 t of lignite in Spain and Malaysia

Occupation examines the direct impacts a land use has during its use time. It is calculated according to the following formula:

Occupation indicator value = $(Q(t_{4,\ ref})-Q(t_{2,3}))$*area used*time of occupation.

So the state after the regeneration of the land is compared with the state during land use.

Figure 2 shows the Biotic Production occupation indicator values for the production of 1 t lignite in Spain compared to the indicator values for the extraction of 1 t lignite in Malaysia. Both graphs are positive, that means there are negative environmental impacts.

The extraction of 1 t lignite in Spain avoids the production of 0.0691 kg biomass; in Malaysia this amount only sums up to 0.0136 kg. The reason is again mainly to be found in the different land use types for the situations t_4 and $t_{2,3}$. The situation in $t_{2,3}$ is for both sites mining area. Obviously, a mining area does not have good land quality parameters. For Spain the situation in t_4 again is moorland, for Malaysia it is fallow ground representing wasteland, meaning that in the example, the regeneration potential of the land in Spain is higher than the Malaysia one. So the moorland does still have higher quality parameters than wasteland, and subsequently the indicator values of the Biotic Production for 1 t lignite in Spain are higher than the indicator values for the extraction of 1 t lignite in Malaysia.

4 DISCUSSION AND OUTLOOK

With the integration of consistent land use information in the GaBi 4 database, for the first time it is possible to examine and to quantify the effects a product or a process has on the land used. The information produced refers to land quality parameters and is summable and scalable over the whole process chain.

However, as this is the first inclusion of such land use information into a database, there are some limitations to be mentioned:

- Land use information is only included in land consuming unit processes.
- Entry data is often derived from databases where only country specific values can be gathered. More site specific values would serve the accuracy of the results. Nevertheless, these values are often difficult to obtain.
- Allocation of transformation effects especially for agricultural processes is not done so far and is subject to further research.

Still the background data provides valuable information which can be used to compare different products on a country scale. For the comparison of exactly located foreground processes or land uses, indicator values can be calculated using LANCA and can be included into unit processes. This procedure allows for a detailed comparison of locations.

In conclusion, the land use database in GaBi 4 gives the user a good starting point in order to determine the main contributors to land use effects. Due to further development of the method, the tool and due to increasing data availability, same as other LCA data, land use data will be periodically updated to ensure up-to-dateness of results.

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