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Scope

Agricultural output has significantly increased in the past 60 years, often at the expense of the environment. The political economic drivers in EU agricultural policy are heavily leaning towards production, where total EU farmers receive some 43 billion euros aid/subsidy a year. However, there has been modest progress in the EU as agricultural subsidies are less linked to production. These changes are a result of policymakers' awareness the present subsidy system will become unaffordable after EU enlargement and as a result of increasing pressure from consumers.

The main soil function still is considered production where others as storing and filtering contaminants, adsorbing organic matter and supplying a habitat and gene pool for biological activity are often neglected (6th Environmental Action Program). A major threat to these functions is soil erosion, whereas it is the active and dynamic topsoil that is most affected by soil loss. Despite the large amount of technical studies devoted to the problem in almost every country, physical and economic consequences of soil erosion on a broad scale remain unknown. This inaccuracy is the logical outcome of insufficient comparable data due to the heterogeneity of the soil loss problem throughout the EU.

This paper is a short research to the availability of data on soil erosion in southern Limburg, the Netherlands. Furthermore, it investigates what can be achieved with this data in a short period (American style). Several organizations such as Waterschap Roer en OverMaas, de Limburgse Land en Tuinbouw Bond (LLTB) and the Province of Limburg are partly involved in the soil erosion matter. In order to develop a sound soil protection policy for Europe it is of vital importance organizations share more information on a national and international scale. Only with full collaboration is it possible to supply

the coming soil protection act with a solid scientific background.

Soil Erosion

Rainfall events are important erosive agents that lead to soil loss. Raindrop impact breaks down soil aggregates and forms particles small enough for transport. The same raindrops form transporting agents, as the spraying about of in water drops entrained particles leads to a (net) down slope movement of soil. The other important transport mechanism is overland flow, caused by total rainfall being higher than infiltration capacity. Overland flow transports vast amounts of soil down slope either as sheet or concentrated flow. The overland flows' scouring and transport capacity increases with velocity and is a function of slope gradient and slope length.

Soil erodibility can be defined as the integrated effect of processes that regulate rainfall acceptance and resistance of the soil to particle detachment and subsequent transport (de Roo, 1993). Factors such as slope gradient, slope length, precipitation intensity and soil type cannot be altered easily. Landuse, on the other hand, can be altered and is as a result widely utilized to decrease soil erodibility and prevent soil loss. Vegetation not only enhances soils acceptance and resistance abilities by providing protection from raindrop impact but also delimits sediment transport by filtering runoff and reducing water flow velocity.

Erosion in the Netherlands

About 3% of Netherlands' surface is affected by wind and water erosion. Erosion in the Netherlands can thus be described as a small problem, since total soil loss involves a relative small part of the country. Nevertheless, significant on- and off-site costs are involved. This research merely details on water erosion in Limburg whereas wind erosion will only be briefly discussed.

Water erosion involves about 61.000 ha. in southern Limburg (figure 1). The area can be considered as a representative for the

loess-covered lands stretching from eastern Belgium through northern Germany. Dry valleys of Pleistocene periglacial origin give the smooth and hilly landscape a pleasant touch. The loess is of aeolian origin, represents prime farmland and is very degradation sensitive (de Roo 1993, Kwaad 1997, Kwaad 2003 and Biolders 2003). The thickness of the loess varies from 2 to 20 meters; the thick loess covers are mainly found on the plateaus while the slopes are covered with colluvial soils.

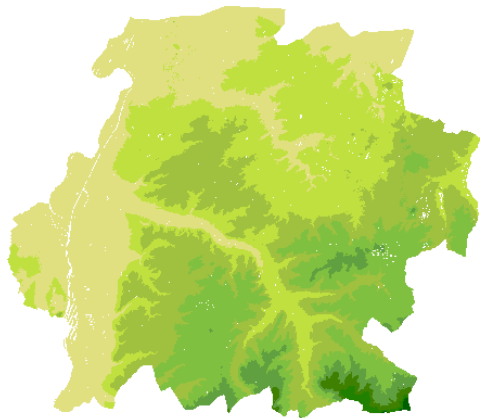


Figure 1: A Digital Elevation Model of South-Limburg. Altitude ranges from 5m in the Northwest to 329m. in the Southeast on an area measuring some 25 km from north to south and 25km. from west to east.

A typical soil loss rate in South-Limburg on 6% slopes under conventional maize cropping was found to be 10.8 ton/ha/yr (Kwaad, 1998).

Since the Roman era, Limburg has been densely populated and widely used for agricultural purposes. Re-allotment of land in the past few decennia has intensified the problem of soil erosion. A large amount of studies along with the short and long term costs involved with soil loss, have prompted the local government to publish an erosion act in 1990 (Erosieverordening 1990). Many studies were published intended to identify the causes and possible solutions in order to attain a sustainable land-usage. In 1995 the rapport (Erosienormeringsrapport) investigated the economic effects involved with soil erosion. In 1991 the Province of Limburg together with the universities of Amsterdam and Wageningen started a project resulting in a physically based

hydrological soil erosion model LISEM (the Limburg Soil Erosion Model). Up to this date the LISEM model is still improved and extrapolated to a wider area. In July 2003 a new erosion act was enforced (Erosieverordening 2003). The act urges farmers to take a series of measures in order to preserve the soils in the area. At this moment the Netherlands and Belgium are collaborating to develop an erosion act for the entire Benelux (Aanpak Erosie in Benelux, Middengebied).

Wind erosion involves some 97.000 ha. in the Netherlands. The areas mainly targeted according to Eppink (1982) are:

- 1) the coastal dunes,
- 2) sandy arable soils in South-Brabant,
- 3) central sections of the Netherlands (Veluwe) and
- 4) the arable raised peat bog soils in the north (Groningen and Drenthe).

Quantitative data on soil loss rates are lacking. This is mainly due to the nature of wind erosion, which does not act point based but rather diffuse over a large area. Economic costs are therefore difficult to estimate since accumulation areas of eroded soil are difficult to identify and soil loss rates on arable fields are unknown due to lack of monitoring.

Impacts and Consequences

Economic costs resulting from soil erosion can be divided in on- and off-site costs.

The on-site costs are directly related to soil loss and include the decline of soil fertility and the washing away of pesticides and fertilizers. Annual crop yield losses can extent from 3 to 5% on the loess belt in Belgium (Bolline and Laurant, 1983). These estimated costs are based on direct erosion damage and re-seeding of average different types of crops. Schouten at al. (1985) mention a higher annual loss of 5 to 10 % in south Limburg. They add, however, these figures are not representative for the entire agricultural area and therefore merely form an indication. Many authors affirm that, from a social point of view, the impact of soil erosion on agricultural productive capacity

is small (Calvatrava-Leyva, 2001). On-site costs are complicated to estimate since extensive monitoring is required for such a task and the heterogeneity of soils throughout the EU makes comparisons and extrapolations difficult.

The off site-costs are related to increasing sediment yields in runoff, which lead to sedimentation of waterways and impose the construction and upkeep of retention reservoirs. Pesticides and fertilizers may be adsorbed to sediment causing pollution and eutrophication where sedimentation occurs. Flooding and particularly muddy floods are of growing concern in North Western Europe (Boardman, 2003). In southern Limburg, Netherlands a questionnaire amongst 15 farmers (Jansen, 1985) revealed 50% of the farmers had erosion or runoff problems on more than 50% of their land. In Wallonia, Belgium Bielders et al (2003) undertook a survey amongst 262 municipalities in the loess belt. 68% of the municipalities were confronted with floods during the past decade while 27% were confronted at least every 2 years over the last decade. The same study revealed only 12.4% of the 1500 questioned farmers did not experience erosion or runoff problems during the past decade.

Farmers

As farmland accounts for 44% (Eurostat, 2003) of all Europe's territory, a strong link exists between agriculture and environment, or rather between land use and soil erosion. As described above, changes in vegetation cover lead to changes in soil resilience, which again influences rates of soil erosion. Farmers are therefore the main targets in the development of soil conservation programs in the EU.

Soils are extra sensitive in spring and to a lesser extent in autumn after the harvest, because of limited vegetation cover and high intensity rainfall. The increased soil erosion in recent decennia can be ascribed to rationalization of agriculture (e.g. increased field size by re-allotment of land and the increases in acreage of row crops). This rationalization of farming

practices can again be described as a response of production pressure inflicted on farmers by local and national governments. Other examples of intensification are the conversion of grassland into cropland, the expansion of spring crops at the expense of cereals and the usage of more developed and heavier machinery leading to soil compaction. Also noted must be the reduced application of organic manure leading to lower organic matter content, which decreases aggregate stability and water retention capacity. The trend towards row crops such as maize, sugar beet, onions and potatoes and the resulting lower acreage of cereals in north-western Europe is likely to increase the frequency of eroding events in the future (Bielders et al, 2003).

Farmers frequently are reluctant to cooperate with new policy, which can be partly explained by the increasing pressure put on them by society in the past 20 years. In the Netherlands legislation on the manure problem was seen as an attack on their rights and large investments were involved to meet regulations. During various discussions with farmers (July, 2003) response often was defensive. Perhaps this author was seen as just another policy maker, preparing just another regulation. More investments for farmers are necessary to prevent erosion, which will only be partially met by subsidies from the government. Nevertheless, farmers' involvement in erosion prevention is (voluntarily or obligatory) increasing.

Measures in Erosion Prevention

Several recognized methods to control soil erosion on croplands are listed on the next page in table 1. The table results from a large questionnaire set up by Bielders in 2003 and describes the percentage of farmers applying measures designed for erosion prevention. It remains unclear, however, whether erosion problems persist despite the adoption of erosion control measures (Bielders et al., 2003).

Percentage of Farmers applying Erosion Control Measures	
Cover Crops	53.2
Contour tillage	36.0
Minimum or no tillage	24.7
Grass buffer strips	23.6
Avoiding 'erosion-prone crops'	14.0
Apply straw/crop residue for surface cover	4.7

Table 1: Erosion control measures implemented by farmers on silt-loam and sand-loam soils in Wallonia, Belgium (Bielders et al., 2003)

From 18 rainfall simulations van Dijk, 2001 determined a correlation of -0.78 between surface cover and runoff and -0.82 between surface cover and splash erosion, both with a significance level of 0.01. Contour tillage prevents rill formation as farmers plough their land parallel to the contour lines (figure 3). Minimum or no tillage positively contributes to surface roughness and therefore increases surface storage of water. Grass strips are popular as erosion prevention measures. If the grass strip has a width of 10m., up to 91% of sediment can be filtered from overland flow (van Dijk, 2001). The province of Limburg realized the effectiveness of strips, which has led to the positioning of a great quantity of these 'strategic grasslands' especially on steeper slopes (figure 2). It follows that conversion of arable land into pasture reduces soil loss to a minimum.

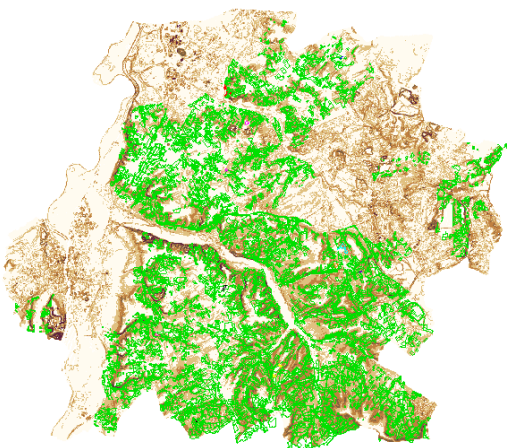


Figure 2: The strategic grasslands as green line elements draped over a slope map of South Limburg. The area most intensively covered is the hilly southeast.



Figure 3: A rill in a sugar beet field with a slope gradient of 4%. Ploughing perpendicular to contour lines may lead to rill formation.

The Soil Erosion Policy

On a national and international scale policy on soil conservation is slowly shifting in the EU. The European agri-environmental program currently provides subsidies for a limited amount of erosion control methods (i.e. grass buffer strips, grass contour strips, cover crops and intercropping). In the Netherlands, starting in July 2003 the agricultural commission LLTB is encouraging farmers to prepare an erosion prevention plan. If they do not several regulations become obligatory.

The erosion prevention measures of the LLTB are designed to:

- 1) prevent overland flow by increasing soils infiltration capacity
- 2) reduce the velocity of overland flow
- 3) prevent the formation of flow-channels
- 4) create an infrastructure for excess water storage
- 5) protect soils for raindrop-impact
- 6) keep soil in situ as much as possible.

It remains an uncertain whether the criteria set by the act (leading to erosion) and the results achieved by counter measures (solving the erosion) are accurate. Available data do not allow

precise and agreeable judgments on soil response to the erratic rainfall.

The following three variables determine what erosion control measures are necessary:

- 1) slope gradient,
- 2) landuse,
- 3) slope length.

Areas can be considered as sensitive to soil loss if they have a high slope gradient and/or an unfavourable landuse. The variables slope gradient and type of landuse can easily be extracted from a raster and will therefore in the following sections be used for analyses of the erosion sensitive areas.

The policy criteria are summarized in table 2.

Slope gradient	landuse	Slope length
slope < 2°	Free	Free
2 < slope < 5°	Limited	Max. 400m.
5 < slope < 12°	Limited	Max. 300m.
12 < slope < 18°	Limited	Max. 300m.
18° < slope	Pasture	-

Table 2: The combination of slope length and gradient together determine the landuse allowed by the erosion-act 2002.

A limited landuse means farmers have to take measures in order to attain 40 (erosion control) points per hectare. Each measure has its own value (fe. Conversion into Pasture 100 points per hectare, contour tillage 25 points per hectare, etc.). Measures are only necessary if landuse consists of erosion sensitive crops, which are maize, potatoes, sugar beet and a few other less common row crops. In Belgium a similar system is used.

Topography

The erosion sensitive area in Limburg is located south of Roermond south of the roads Sittard-Urmond and Sittard-Wehr. It has a total size of 609 km². The majority of the gentle but hilly landscape has a slope gradient below 12% (97%) and only 0,7% a gradient of more than 18% (table 3). Above 18% farmers must convert arable land

into pasture because of the high erodibility of the terrain.

slope gradient (percentage)	land area (km2)	percentage
slope < 2	258	42.3
2 >= slope < 5	224	36.8
5 >= slope < 12	103	16.9
12 >= slope < 18	15	2.4
Slope >= 18	4	0.6
no data	5	0.9
total	609	100

Table 3: Total land area in absolute numbers and as a percentage of the five slope gradient categories.

The area with the highest gradients is located in the southeast of Limburg. This area is dissected by the Geul-valley (clearly visible in figure 4 that drains into the Maas river on the western border with Belgium, running from south to north).

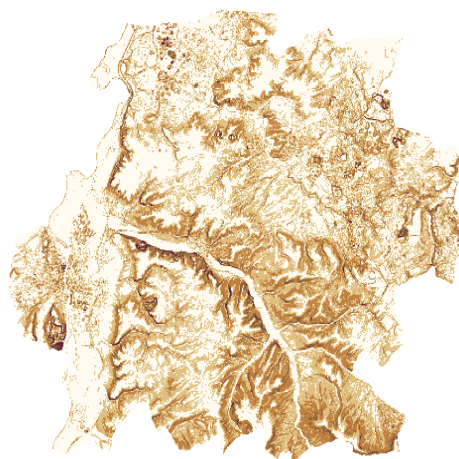


Figure 4 The slope gradient in South-Limburg. The light coloured areas correspond with a gradient of less than 2%, while the darker areas have a gradient of up to 22%.

According to de Roo, 1993 two thirds all soil erosion phenomena occurs on slopes with gradients less than 5%. Furrow erosion occurs predominantly on slopes less than 2%, rill erosion on slopes between 2 and 5% and gully on slopes between 5 and 8%. These figures imply the LLTB may have to tighten its regulations.

Landuse

In the Netherlands in the year 2000, of the total 41.500 km² land-surface 56.0%

is used for agriculture. In Limburg in the same year this percentage is slightly higher with 57.9% (CBS, 2003) and in the hilly, erosion sensitive area 54.2%. During the past 10 years these areas are gradually decreasing where arable land is converted into nature or build-up area. Some cropland is converted into pasture, with financial aid of the European Community. Eurostat reported that in the entire Netherlands 1522 km² of arable land was converted into pasture in 1997 alone (Vidal, 2001). Soil loss is almost brought to a halt by using grass as cover crop.

Of main interest is the land used for agricultural purposes because this land covers more than half of the area and contributes most to total soil loss in absolute numbers. The main erosion sensitive crops are: maize, potatoes, beet, onions and other less common row-crops (LLTB 2002, Kwaad and de Roo 2003). Farmers are urged and obliged to reduce total acreage of these crops in favour of grass and cereals (Erosieverordening, 2002). Even though both cereals and a grass cover strongly reduce the soils' erodibility, production in terms of euros per hectare is also reduced. This clearly shows a major inconsistency in policy since the EU subsidy system encourages farmers into producing more while on the other hand the same farmers are held back because this increase in production brings along negative environmental aspects (fe. soil erosion).

In table 4 all different landuses are divided into the three main categories agricultural land, build-up area and nature.

	1994	1997	2000
agricultural land	58.1	55.6	54.2
Build-up area	33.1	35.2	36.0
nature	7.5	7.9	8.4
Total (%)	100	100	100

Table 4: Landuse change in percentages of the total area (609km²) of South-Limburg in the years 1994, 1997 and 2000.

Table 4 follows from analyses of the land-use files (LGN) covering southern Limburg (figure 5). The files consist of a raster with a grid-size of 25m and cover the periods: 1994, 1997 and 2000. Each raster has a maximum of 46 unique values

corresponding with a particular landuse. The rasters are based on at least two Landsat satellite photos, one in spring the other one in midsummer.

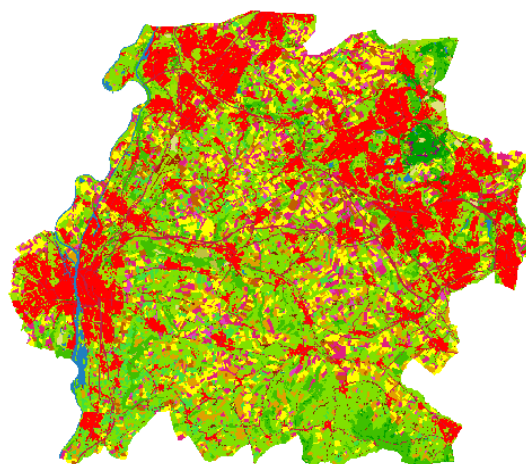


Figure 5 Landuse in South-Limburg, the reds correspond with build-up areas, the yellows and light greens with arable land and the dark greens with forrest. Raster made by Alterra, Wageningen.

A more detailed overview of landuse changes in this period is listed in table 5.

Land-use (ha.)	1994	1997	2000
Grass	14379	17050	15325
Cereals	5538	5186	5781
Maize	4485	2811	3661
Potatoes	1690	1715	1694
Sugar beet	3545	3240	3464
Bulbs	1364	2268	2135
Other agriculture	4332	1561	921
Orchards		4	4
Total agriculture	35332	33835	32985
Build-up area	10832	12020	12041
Main road and rail systems	3119	3075	3072
Build-up area in open land	113	152	148
Forest in build-up area	933	809	789
Grass in build-up area	4725	4208	5017
Uncovered wasteland	424	471	215
Build-up area in agri. land		667	602
Total build-up-area	20146	21401	21884
Deciduous forest	3684	3925	4149
Coniferous forest	626	620	624
Other nature	261	243	355
Total nature	4571	4788	5129
water	779	781	808
no data	27	48	48
Total land area	60854	60854	60854

Table 5: Detailed landuse change in hectares in South-Limburg in the years 1994, 1997 and 2000.

Agricultural area has decreased with an annual 1.15% since 1994 or with 6.6% from 35.332 ha. in 1994 to 32.985 ha. in 2000. Changes in crop choice can be realized within a year and are invoked mainly by economic factors.

The agricultural landuse in absolute numbers is illustrated in figure 7 and in relative numbers (divided by total arable land) in figure 8. Grassland changes are illustrated separately in figure 6.

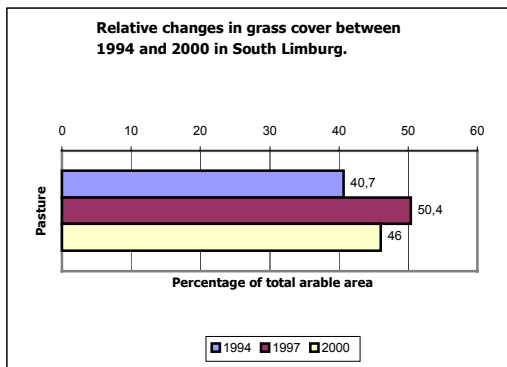


Figure 6 Relative cover of pasure of the total area arable land.

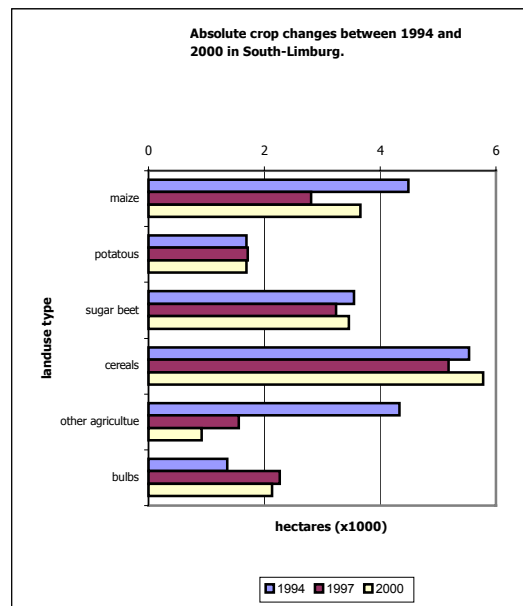


Figure 7: Farmland changes between 1993 and 2000 in South-Limburg in hectares.

The erosion sensitive crops maize and sugar beet have lost terrain. Between 1994 and 1997 their plunge was greatest and benefited pasture (figure 6). There is a clear tendency towards monoculture as is illustrated by the decline in the category 'other agriculture'. Cover by cereals has increased especially in relative numbers. Flower bulbs are strongly gaining terrain.

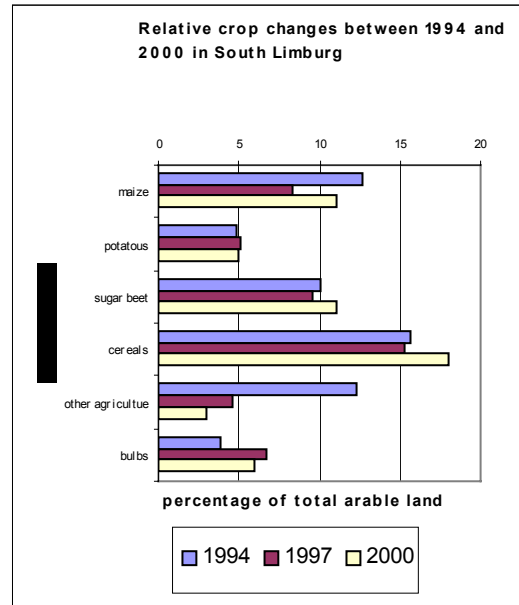


Figure 8: Relative farmland changes between 1993 and 2000 in South-Limburg, divided by total arable surface.

Slope gradient has a large influence on landuse illustrated in figure 9. The percentage of grassland increases with slope gradient, which is conform the erosion act. Nevertheless there are still erosion sensitive crops on slopes steeper than 18%.

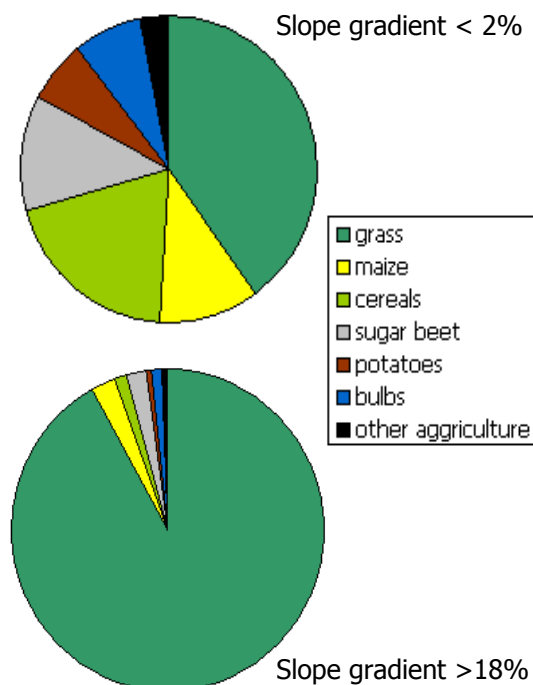


Figure 9: Landuse changes with slope gradient. Area with slope gradient <2% is 25755 ha. and area with slope gradient >18% = 377 ha.

Conclusions

Although regulations should be tightened further to reduce soil loss, there seems to be progress in the development of a sustainable land use in Southern Limburg. Also on international basis cooperation is on the rise.

The gathering of spatial data proves to be a complex and time-consuming task as the primary rights to the information is distributed over a range of organisations. Therefore all different spatial data should be concentrated into one national or preferably international institute where it would be easy and free accessible for research purposes.

Literature about the soil erosion problem is difficult comparable because it lacks a standard, which could in the future be set by the EU.

Bibliography

Rasters

Altitude files with a gridsize of 25m, Meetkundige Dienst Rijkswaterstaat.

Land use files Netherlands, (LGN2, LGN3 and LGN4 files with a gridsize of 25m, (based on Landsat Imagery), Alterra, Wageningen.

Strategic Grass Lands, GIS Department, Waterschap Roer en Overmaas.

Literature

Biëdiers C.L., Ramelot C., Persoons E., 2003, Farmer perception of runoff and erosion and extent of flooding in the silt-loam region of the Belgian Walloon Region, *Environmental Science & Policy* 6, 85-93.

Boardman J., Poesen J., Evans R., 2003, Socio-economic factors in soil erosion and conservation, *Environmental Science & Policy* 6, 1-6.

Boardman J., 2003, Evans R., Ford J., Muddy floods in the South Downs, southern England: problem and responses, *Environmental Science & Policy*, 6, 69-83.

Calatrava-Leyva J., Gonzales-Roa M.C., 2001, Approaches to the Economic Analysis of Erosion and Soil Conservation: a review, *Proceedings of the World*

Congress on Soil Erosion Research for the 21st Century, Honolulu, Hawaii.

Dijk P. van, 2001, Soil Erosion and associated sediment supply in rivers, isbn90-6787-059-5, Thesis University of Amsterdam, IBED, p. 211.

Erosieverordening (Aanpak erosie en wateroverlast), 2002, Werkgroep Limburgse Land en Tuinbouw Bond.

Jansen, L., 1985, Erosie in het lossgebied, Stage uitgevoerd in opdracht van de Landinrichtingsdienst te Roermond, LUW-Vakgroep Cultuurtechniek, Wageningen.

Eppink L.A.A.J., 1982, A survey of wind and water erosion in the Netherlands and an inventory of Dutch erosion research, *Mededeling Vakgroep Cultuurtechniek*, no. 59, Wageningen, p.40.

Kwaad F.J.P.M., Zijk van der P.M., Dijk van P.M., 1998, Soil Conservation and maize cropping systems on loess soils in the Netherlands, *Soil & Tillage Research* 46, 13-21.

Kwaad F.J.P.M., de Roo A.P.J., 2003 (in press), Soil erosion and conservation in the Netherlands.

Roo de, A.P.J., 1993, Modelling surface runoff and soil erosion in catchments using Geographical Information Systems, ISBN 90-6266-098-3, *Nederlandse Geografische Studies* 157, Utrecht, p.293.

Schouten C.J., Rang M.C., Huigen P.M.J., 1985, Erosie en Wateroverlast in Zuid-Limburg, *Landschap*, themanummer erosie 2-2, Werkgroep Landschapsecologisch Onderzoek, Delft, Netherlands.

Verstraeten G., Poesen J., Govers G., et al., 2003, Integrating science policy and farmers to reduce soil loss and sediment delivery in Flanders, Belgium, *Environmental Science & Policy* 6, 95-103.

Vidal, C., 2001, Extensive areas account for at least 42% of agricultural land, *Statistics in focus*, catalogue: KS-NN-01-023-EN-I, European Community.