

# Prototypical Policy Impacts on Multifunctional Activities in rural municipalities

A collaborative project under the  
EU Seventh Framework Programme



## LINKAGE OF IMAGE AND LEITAP, PROVIDING A MODELLING FRAMEWORK FOR AGGREGATED MODELLING

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PRIMA aims to develop a method for scaling down the analysis of policy impacts on multifunctional land uses and on the economic activities. The scoped policies will include the cohesion policy (ERDF, ESF, CF), the enlargement process (IPA) & the rural development policy (EAFRD) of the European Commission, with a special focus on agriculture, forestry, tourism, and ecosystem services. The approach will: rely on micro-simulation and multi-agents models, designed and validated at municipality level, using input from stakeholders; address the structural evolution of the populations (appearance, disappearance and change of agents) depending on the local conditions for applying the structural policies on a set of municipality case studies. Involving eleven partners, the project is coordinated by *Cemagref*.

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## GENERAL INFORMATION

Task(s) code(s): M5.2

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Related milestones: -

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## EXECUTIVE SUMMARY

This report provides a short description of the method in which the general equilibrium model of the world economy LEITAP is coupled with the land allocation module of IMAGE. The IMAGE model is run at the Environmental Assessment Agency (PBL) in the Netherlands, and the LEITAP model is run by the agricultural research institute LEI in the Netherlands. IMAGE runs generate information about land availability and its productivity, which is used to model land supply in a stylized way in the LEITAP model. The LEITAP model generates next to a lot of economic results, data about agricultural production and land use that are sent to IMAGE to allocate land use on grids of half grades (50x50 km<sup>2</sup>). This information can be used to calculate greenhouse gasses and biodiversity indicators on a world-wide scale. For the PRIMA project this is not immediately relevant because the resolution is not sufficient to give clear results per country. The interaction between LEITAP and IMAGE is standardized, so the system runs with a minimum of human intervention (except for sending and downloading the data).





# 1 INTRODUCTION

## 1.1 Objective

The objective of the task behind this report is to link IMAGE and GTAP “to provide a working modelling framework supporting interactions between sectoral production growth rates, with the use, productivity and intensity of land from GTAP and the demand for land and environmental indicators from the IMAGE model.” This objective had to be adjusted a little bit, because the IMAGE model is very much suitable for environmental indicators on a global scale, but not to provide them on a local scale. For this reason, the focus of the project will be to downscale results from the adjusted version of the GTAP-model, called LEITAP. The challenge of this task is to create a running LEITAP model using the information from the IMAGE model in the most efficient way. This information is mainly the land supply information.

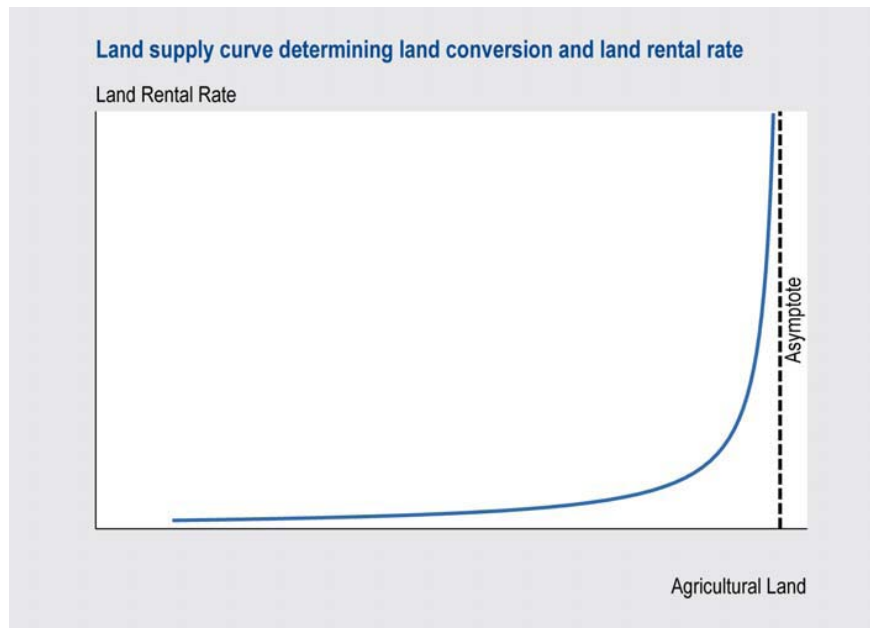
In this document we focus on the technical implementation of the coupling procedure.

## 2 COUPLING OF IMAGE AND LEITAP

In the past LEITAP and IMAGE have been coupled as an interactive process. This didn't work out correctly, and seemed overly complicated. For this reason the coupling has been simplified a lot. The coupling is now a one way process. First, a land supply curve is calibrated for LEITAP based on information from IMAGE. Second, information from IMAGE about the differences in productivity from different grid cells and the way IMAGE allocates land to these grid cells, a correction factor for LEITAP is derived and implemented that corrects for the difference between marginal and average productivity.

### 2.1 Land market

The land market in standard GTAP is extended with an explicit land supply function. This is done at the level of national states within the EU and some large countries of the world, and regions consisting of more countries in the rest of the world. The basic idea is that supply of agricultural land depends on average land price. This land price is calculated as a weighted average of land prices for different land uses, and that an increase in agricultural land price either implies less urban land use, or less land use for nature. The asymptote shows the maximum amount of land that is available for agriculture, and it seems plausible that land price increases when agricultural land use increases.



It is not easy to find a good foundation for land supply elasticities. In the past they were based as much as possible on the land suitability values used in the IMAGE model. It was assumed that these elasticities decrease till 0 when all available land in a country is used. Knowing now that the suitability values in IMAGE have not much to do with land prices, we implemented an easier approach, where the price elasticity of land supply is generated by the following function:

Formula (all,r,REG) LPEL(r)=  

$$\{[\text{ASYMPTOTE}(r)/\text{LANDSUPPLY}(r)]^2\} * \text{LANDPOW}(r) * (\text{ASYMPTOTE}(r)/\text{LANDSUPPLY}(r) - 1);$$
 Equation LANDSUPPLY1  
 (all,r,REG) p\_landsupply(r) = p\_asymptote(r) + LPEL(r) \* p\_lprice(r)

Where LPEL is the price elasticity of land supply, Landsupply is the current amount of land used, asymptote is the amount of land available in km<sup>2</sup>, p\_lprice is the percentage change in price, and LANDPOW is a coefficient, normally set at 1. This function creates an elasticity of land supply of zero when landsupply equals the amount of available land, and approaches infinity when land use approaches zero. When only 50% of available land is used, the price elasticity of land supply is 4 at a LANDPOW of 1. By changing LANDPOW the curvature of the function can be changed.

### 2.1.1 LEITAP land supply and IMAGE land suitability

The calibration of the land supply elasticity function is based on the land suitability curve as used for the land allocation in the IMAGE model. Grids are defined for 0.5x0.5 degree spatial resolution, about 50x50 km, and for each grid cell IMAGE calculates suitability based on a very rough indicator function. Suitability is the sum of indexed suitability between 0 and 500 for population density, distance to main water infrastructure, and a random factor, with land productivity having a negligible influence. It adds an indicator





between 0 and 1 to the calculated suitability, where cells with land productivities of less than 10% of the maximum are not included in the land allocation procedure. This implies that there are enormous differences in land productivities of cells with the same suitability. Land is allocated from highest to lowest land suitability, starting from the current land allocation.

The suitability information may be used to derive a land supply function for LEITAP. But this is a risky business. For suitability only an ordinal scale is required, while land price is a cardinal scale. But in weighting the different elements of suitability index, some cardinality is also implied. For example, with a population density index of 500 an increase of 1 in distance to infrastructure is assumed to have the same effect as the increase of 1 in distance to infrastructure with a density index of 200. So, the better the suitability index in IMAGE is based on a correct and statistically estimated function, the better will be the cardinal properties of the index.

In first instance, we used from IMAGE price elasticities of land supply derived from the IMAGE suitability curves. But knowing now that the cardinal properties don't have any meaning, we decided to standardize all land supply curves with a LANDPOW of 1 for all countries. This makes very explicit the assumptions. Further research into the topic of land supply curves would be valuable to improve on this very rough assumption, but this research is outside the scope of the project.

## 2.2 The calibration of the parameters of the land supply curve

Not much has to be calibrated, except for generating a reasonable land price. The land price is defined as the land value at market price divided by land supply (that equals land demand):

```

Coefficient (parameter) (all,r,reg) LANDVALUE(r) # Value of
land #;
Formula (initial) (all,r,REG) LANDVALUE(r) =
sum{j,PROD_COMM,VFM("land",j,r)};
Variable (levels) (all,r,REG) LPRICE(r) #Land price in re-
gion r#;
Formula (initial) (all,r,REG) LPRICE(r) = LAND-
VALUE(r)/LANDSUPPLY(r);
COEFFICIENT (parameter) (all,r,REG) TEMPLPRICE(r);
Formula (initial) (all,r,REG) TEMPLPRICE(r)=LPRICE(r);
WRITE TEMPLPRICE to file GTAPVIEW header "TLPR";
Equation LPRICE1 (all,r,REG) p_LPRICE(r) = pfactreal("land"
,r);

```

The land price calculated in this way is too small to get good numerical results. Therefore, we multiply this price by 200 to get more or less useful numbers. An alternative would have been to redefine the dimension of land in 100 km<sup>2</sup>, instead of plain km<sup>2</sup>, but this would make the text less easily to read. The point is to have readable and manageable numbers without having computation problems. Because GEMPACK is doing calculations with single precision, rounding errors of extremely large or small numbers may be large.



### 2.2.1 *Towards a dynamic land supply function?*

The theoretical foundation for the land supply curve is not clear a priori. Suitabilities may change when new infrastructure is developed, and part of the investments in making land suitable for agriculture can be seen as fixed costs. So, in the long run a dynamic version of land supply seems to be useful.

### 2.2.2 *Marginal versus average land productivity*

Potential land productivity in the IMAGE model is determined mainly by climate and soil parameters. Actual land productivity is a fraction of potential land productivity that is the same within one region. Because in some countries cities were growing around relatively high productive land, marginal land productivities tend to decrease with additional land taken into account. But there are also countries where the most productive land is not used, perhaps because civilization started around sea infrastructure.

The information about land productivity of land that is taken into account is used to adjust land use changes calculated in standard GTAP for productivity. For example, if land use increases with 1% in economic efficiency units, while marginal productivity is 90% of average productivity, then (1/0.9)% instead of 1% extra hectares are required.

The question arises to what extent also the amount of labor and capital differ on these extra lands with a lower productivity. This is not very clear. If you have a lower land productivity and need the same amount of labor on the land, then labor demand has to be corrected with the same factor. But probably the land will be used more extensively, implying that less labor is applied on this land (with an extra decrease in productivity that may or may be not included in the land productivity results of IMAGE). Because we don't know the net effect, we for the moment assume that more land is needed for the same amount of production, while the other factor inputs per unit of product remain the same (and therefore decrease per hectare). We assume that the increase in land required for the same amount of product is found back in the land price per hectare, implying that the land price per economic unit of land remains the same.

For the moment these assumptions help to guarantee that land productivity is consistent with IMAGE land allocation. Further theoretical and empirical insights may improve these adjustments.

#### *Practical implementation*

Based on data from IMAGE, Average/marginal productivity as a function of land use is estimated as a cubic equation. The parameters are read in the coefficient AMLANDCOEF, and used to calculate a coefficient AMLANDPROD for each step. This parameter corrects the land use change in economic units (qfe) into physical hectares (Equation P\_LANDUSE1).



```

Set AMCOEF (a ,b,c,d);
Coefficient (parameter) (all,i,AMCOEF) (all,r,REG) AM-
LANDCOEF(i,r)
    #Average/Marginal productivity of land#;
Read AMLANDCOEF from file GTAPPARM header "AMLC";

Coefficient (all,r,REG) AMLANDPROD(r) #Aver-
age/Marginal land productivity#;
Formula (all,r,REG) AMLANDPROD(r)=1;
Formula (all,r,REG:MODELCHOICE("LandSupplyOn")=2) AM-
LANDPROD(r)=
    (AMLANDCOEF("a",r)
    +AMLANDCOEF("b",r)*REGLANDUSE(r)
    +AMLANDCOEF("c",r)*REGLANDUSE(r)^2
    +AMLANDCOEF("d",r)*REGLANDUSE(r)^3);

Equation P_LANDUSE1 (all,j,PROD_COMM)(all,r,REG)

p_landuse(j,r)=AMLANDPROD(r)*sum{i,ENDWL_COMM,qfe(i,j,
r)};

```

#### *Estimating coefficients for marginal-average correction*

In order to estimate the coefficients for the marginal-average correction from the data received from PBL, the following steps have to be taken.

- 1) Data about average/marginal productivity are received from PBL; they have to be extracted in subdirectories in the directory V:\CleanLeitapDevelopment\DatabasesUsed\LANDDATA\_PBL. Into this directory an Eviews workfile avmarg.wfl, an Eviews program file createdata.prg and a program created by Delphi, called RenamePBLDataFilesProject.exe have to be added in the subdirectory with the name of the scenario and margprod have to be copied in. In the case without forest of data received from PBL on March 05 2009 may for example be called V:\CleanLeitapDevelopment\DatabasesUsed\LANDDATA\_PBL\5mrt2009\landsupply\_WoF\margprod.
- 2) Two levels higher, so in this example in the directory V:\CleanLeitapDevelopment\DatabasesUsed\LANDDATA\_PBL, a file regio.txt should be stored, where the region names as used in the simulations are stored for use by the program RenamePBLDataFilesProject.exe. Add also at this level a file with the land use data as used in the basedata file, called landuse.txt. This is used in the Eviews program to correct the asymptotes for the difference in current land use between PBL data and GTAP data.
- 3) To create the data, first run the program RenamePBLDataFilesProject.exe, and click on the only button in the window. This renames all datafiles received from PBL about marginal productivities. Then double click on the Eviews workfile avmarg.wfl, and if there are already data in it, you may delete everything except the vector c and the variable resid, which are system variables that can not be deleted.



- 4) Then select in Eviews under Options, File Locations, and fill in as current data path the path that you are using (last subdirectory is Margprod). Then you may open the program Createdata.prg and this should generate the data automatically.
- 5) You may copy the vector aaasymptote to the correct place in the basedatafile (asymptote). And copy the matrix aareults in the correct place of the parameter file (amlandcoef)
- 6) Then run the program CREATELANDPAR.bat in the root of the simulation directory. If something goes wrong check the cmf-file.
- 7) Import the landpar en landpow variables in the parameter file, and check if none of the landpar parameters is zero. If this is the case, then adjust the price elasticities of land supply in the basedata file downwards for these countries. And repeat from step 6 again till all landpar for all scenarios are less than zero.

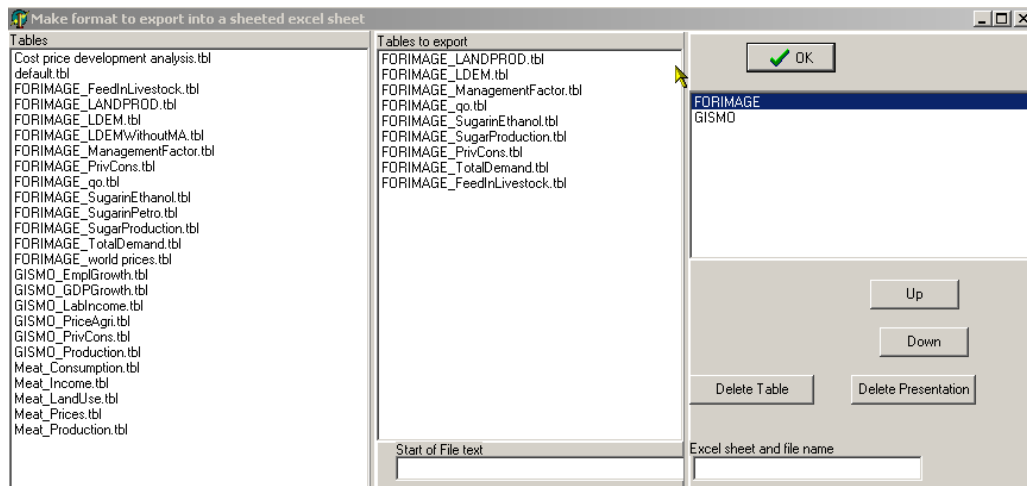
### 2.2.3 Using non-default supply functions

Depending on different scenarios different supply functions may be used. Because we standardized all functions for all countries, except for the current price/land use combination, only the amount of available land, the asymptote, has to be adjusted for different scenarios with respect to regulation about what land may be developed for agricultural purposes.

## 3 THE USE OF LEITAP INFORMATION FOR IMAGE

In order to facilitate the exchange of information FROM LEITAP to IMAGE we have developed a procedure where the files required for the IMAGE model are automatically generated. A program has been developed, GEMSE\_Analist (programmed in Delphi), that is able to combine the information from all the files from all the periods and scenarios that have been run. In this tool an export utility for tables has been created that is specifically focused on the input needs of the IMAGE model

The export utility for tables is a function with the same principles as making a presentation. But it not only creates a presentation that is shown under “Active Presentation”, but also creates a text file and an excel tab file per table. It is primarily designed to export files for use in the IMAGE program. If you select under the main menu item Presentations, Export Utility, you will get the following window:



You can select tables by moving them from the left to the middle box, and delete and move them. You can add a text in the box below. The text entered in “Start of file text” is put at the start of the ASCII file that is made for IMAGE, and you can give a name for the variable that is put in the file. Where this name is used in the name of the ASCII file, the name of the tabsheet of the EXCEL file where the table is stored, and in the starting information of the ASCII file in a way that IMAGE can read it. Click on OK, and give it a name that clearly describes what it is doing.

When created, you can select the export utility, in this case “ForImage” and the tables are presented in the main menu under “Active Presentation”, but also automatically stored in the subdirectory “Outputdata”, where the file-names are defined with the name of the export presentation, followed by the scenarioname and the data. There is an excel file, a subdirectory, and a zipfile created according to this format. In the zipfile and the subdirectory, each file is a textfile with the table. These can be send directly to IMAGE.

In summary, the export utility creates the possibility to create all files needed in the IMAGE model by pressing only on button. The procedure has a lot of flexibility to adjust to changing needs of the IMAGE model.



## 4 CONCLUSION

The coupling between IMAGE and LEITAP is accomplished through land availability and a correction factor for the difference between marginal and average productivity. This document describes the technical implementation. A procedure has been developed to generate the data needed for IMAGE in a standardized way that can be adjusted flexibly when the needs of the IMAGE model changes.

The LEITAP results will be the main input for the downscaling exercise to be accomplished in PRIMA. The focus of this exercise will be on production and land use results of the simulations. The land use results will depend to a large extent on the information provided by IMAGE, and included in the LEITAP model. The international modelling system that is created with LEITAP-IMAGE guarantees that the EU is not taken into isolation, but that also the feedback of policy changes or changes in driving forces through the rest of the world will be taken into account.