Implementation of an economic valuation module in the Land Use Scanner model

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Summary

As part of the *'Deltaplan veengebieden'* project PBL Netherlands Environmental Assessment Agency has asked VU Amsterdam to participate in the development and implementation of an economic valuation module in the Land Use Scanner model. This module can be used to help monetise the location-specific costs and benefits associated with various agricultural crops and production strategies under different socio-economic, climatic and biophysical conditions. Based on this economic valuation of the production potential for different crops and strategies, Land Use Scanner is able to simulate the local competition between crops and production strategies and provides the spatial patterns that may result from anticipated changes in, for example, groundwater levels and agricultural subsidies. This module will focus specifically on agricultural production options in the peaty meadow areas of the Netherlands will simulate spatial patterns in agriculture land use that may result from anticipated changes in, for example, groundwater levels and agricultural subsidies.

The following main issues regarding the development and implementation of the module are addressed within this report:

- review relevant literature on the local characteristics that define the suitability for agricultural production (with particular reference to incorporating the impacts of groundwater fluctuation);
- assess the added value of including detailed parcel registration data in Land Use Scanner (as opposed to the LGN-data currently used by PBL);
- provide a short description of the Net Present Value methodology that is central to the valuation module;
- describe how the valuation module can be implemented in Land Use Scanner

1. Local characteristics defining the suitability for agricultural production

The biophysical suitability for agricultural crops is a factor of local features such as soil type, topography, climate and hydrological conditions. Methods to map biophysical factors at global level and then translate them into attainable yields and productivity have been devised, such as IIASA's Agro-Ecological Zones model (Van Velthuizen et al., 2007; Fischer et al., 2012). This model allows determining attainable yields in a spatially-explicit way according to evaluation of agro-climatic and –edaphic conditions and constraints, and assessment of productivity gaps due to differences in rate of technology adoption. While such methods are a valuable source of information and input to various global and regional applications, its spatial resolution is too coarse to be implemented in assessments at the national and local levels.

The Her-Evaluatie van Landinrichtings Plannen (HELP) system (Brouwer and Huinink, 2002; Van Bakel, 2007) has been widely used to spatially represent crop biophysical suitability in Dutch case studies (e.g. van der Hilst et al., 2010; Diogo et al., 2012; Kuhlman et al., 2013). In this method, maps of groundwater level and soil type are combined to determine the degree of yield reduction, in relation to the maximum attainable crop yield, resulting from the damage caused by drought and water surplus. Crops differ in their tolerance to water stress and water surplus, which can both inhibit crop growth. Too dry conditions during spring can reduce soil moisture and thus decrease availability of water for crops (if not irrigated), leading to delayed seed germination and poor crop emergence. On the other hand, too wet conditions can lead to saturation of the root zone, resulting in reduced root development and root rotting, deficient nutrient uptake and impediment of gas exchange of oxygen and carbon dioxide within the root zone. Water logging can also cause indirect damage by preventing machines to be taken to the field, thus delaying operations such as spraying and harvesting, and by promoting the occurrence of certain pests and diseases.

In the HELP system, the estimation of yield reduction takes into account not only direct damage but also indirect damage (e.g. loss of product quality due to harvest delay resulting from the impossibility of operating machines in heavy soils when they are wet). Total yield reduction is then calculated as follows:

$$\mathrm{D_{tot}} = \mathrm{D_{wa}} + \left(\frac{100 - \mathrm{D_{wa}}}{100}\right) * \mathrm{D_{dr}}$$

where:

D_{tot} is the total yield reduction

D_{wa} is the yield reduction caused by water surplus

D_{dr} is the yield reduction caused by drought

The HELP system was last updated in 2006 (van Bakel, 2007) and currently includes the definition of biophysical suitability for the main types of crops in the Netherlands (potatoes, beets, cereals, grass, silage maize, vegetables, fruits, flower bulbs and tree nursery), based on the combinations between 14 soil types and 11 water level classes. This method has the advantage of being readily available and covering the full extent of the country.

However, some criticisms have been raised, questioning the accuracy and usefulness of the HELP system. Firstly, drought direct damage function is based on a quasi-stationary hydrological model (LAMOS) using outdated climate data. The extent of crop damage due to water stress/surplus depends in a combination of factors such as precipitation patterns, soil type (which determines soil drainage conditions), temperature (which affects the rate of oxygen depletion) and biological activity in the soil. Therefore, although groundwater levels contribute to crop biophysical suitability, considering it as an independent factor is not enough to determine suitability in case other (climate) factors also change. Secondly, water surplus damage was calibrated according to expert judgement, but the calibration process has not been fully documented. Thus, the method has a low degree of transparency. Finally, parameters related to indirect damage are based on outdated technology from previous decades, and therefore they do not reflect current management practices dealing with non-optimal conditions.

As a result, a major revision of the HELP system is currently ongoing (Bartholomeus et al., 2013). New meta-relationships between crop yields and hydrological conditions are being established based on SWAP model. SWAP is an agro-hydrological model that simulates transport of water, solutes and heat and actual evapotranspiration of crops as a function of meteorological data (precipitation, evaporation and temperature), combined with crop and soil data (Feddes and Raats, 2004). These new meta-relations will allow obtaining yield reduction maps based on up-to-date crop damage functions related to drought, water surplus and water salinity, for both current and future climate conditions. However, the revision of HELP system is still at its initial stage of development and thus a complete version should only be expected to become available in forthcoming years.

Other alternative approaches to represent crop biophysical suitability are also currently being developed, for example:

- MetaSWAP+WOFOST model coupling - WOFOST crop growth model determines crop productivity by simulating processes such as photosynthesis and respiration according to transport of materials and heat simulated by SWAP model. First model applications have been developed and tested for grass (Kroes and Supit, 2011).
- Groundwater To Stress Transfer (GTST) model - originally developed to simulate nature vegetation growth, crop productivity is hereby determined as a function of oxygen stress, which in turn depends on factors such as groundwater level and soil moisture, texture and temperature. Model applications to determine grass and potatoes have shown promising results (Witte, 2013).

However, similarly to the revised HELP system, it will take time until model applications for all crops become fully developed and available. Therefore, it can be concluded that, for the time being, the current version of HELP system appears to be the best available option to represent crop biophysical suitability in a spatially-explicit way.

2. Added value of including detailed parcel registration data in Land Use Scanner

LGN6 land-use/cover dataset has been used to represent agricultural land-use patterns in the most recent versions of Land Use Scanner. The majority of LGN6 agricultural land-use classes are clearly defined as specific crop types - agricultural grass, maize, potatoes, grains, sugar beet, flower bulbs, tree fruits, fruit nursery, tree nursery. Yet this data set lacks the spatial and thematic detail of Base Registration Parcels (BRP) dataset compiled each year by the Ministry of Economic Affairs. This is a census dataset based on farm surveys regarding crop grown at the plot level.

To assess the added value of including detailed parcel registration data in Land Use Scanner a pixel-to-pixel comparison was made for the LGN6 land-use map and a map combining BRP datasets for 2007 and 2008 according to the same geographical coverage of LGN6 satellite images. Table 1 shows the agreement between agricultural classes in LGN6 land-use map and the combined BRP datasets for 2007 and 2008. It can be seen that most classes have a high level of agreement. However, there is one class in LGN6 that appears to be more ambiguous, "Other Crops". This class is defined as "an agricultural parcel with crops that are not included in the previous classes" (Hazeu et al., 2010). Different types of crops seem to be included in the same class – vegetables and horticultural crops and arable crops such as onions, rapeseed and hemp. Furthermore, the classification accuracy of this class is rather low, since it appears to have a relatively high level of agreement with many different crop types such as grass, corn, potatoes and grains.

Table 1: Agreement between LGN6 and BRP 2007/08 classes

		BRP 2007/08											
		Agric. grass	**Corn**	**Potatoes**	**Beets**	**Grains**	**Onions**	**Other arable crops**[1]	**Fallow**	**Vegetables**	**Flowers**	**Fruits**	**Tree nursery**
LGN6	**Agric. Grass**	91.8%	3.6%	0.7%	0.2%	1.2%	0.0%	0.2%	0.5%	0.4%	0.2%	0.1%	0.2%
	Corn	8.0%	78.5%	3.7%	3.3%	1.8%	0.2%	0.3%	0.4%	1.9%	1.1%	0.1%	0.5%
	Potatoes	6.8%	8.0%	72.2%	2.0%	3.7%	0.5%	0.9%	0.6%	4.3%	0.4%	0.0%	0.2%
	Sugar beet	1.7%	8.2%	3.2%	75.7%	3.6%	0.7%	0.4%	0.7%	4.2%	1.2%	0.1%	0.1%
	Grains	6.4%	2.1%	4.5%	1.4%	80.2%	0.5%	1.1%	0.6%	1.9%	0.5%	0.1%	0.4%
	Other crops	11.9%	8.6%	9.2%	4.2%	12.3%	18.0%	5.7%	1.3%	22.8%	3.3%	0.4%	1.7%
	Flower bulbs	4.5%	2.0%	2.2%	0.7%	4.9%	1.1%	0.9%	0.9%	7.2%	74.0%	0.1%	1.3%
	Fruits	5.5%	1.4%	1.1%	0.5%	1.6%	0.3%	0.6%	0.4%	0.6%	0.3%	86.6%	0.7%
	Tree nursery	7.4%	9.3%	1.5%	1.8%	2.6%	0.2%	1.6%	2.2%	2.7%	5.1%	2.5%	60.5%

[1] "Other arable crops" include industrial crops such as rapeseed, flax and hemp

Furthermore, BRP classification has a more detailed classification, distinguishing between crops within the same general group, such as different types of potatoes (starch, consumption and seed potatoes) and different types of grains (e.g. winter and summer wheat, winter and summer barley). This more refined classification can be linked with specific economic data on production costs regarding these crops (e.g. using data from van der Hilst et al., 2010) and thus improve the characterization of the economic performance of arable farming systems.

Crops are usually grown in rotation schemes, in which different crops are sequentially grown in the same plot season after season. Farmers implement this practice in order to improve soil structure and its chemical and biological environment, as well as distributing financial risks over different crops. BRP is collected and updated every year, which allows performing a more detailed analysis of crop rotation schemes and land-use changes over time. Therefore, BRP data series should be preferred over LGN to study spatial patterns of agricultural land-use.

Due to crop rotation practices, a certain degree of aggregation is required in order to correctly represent the spatial distribution of different types of farming over time. Previous studies on agricultural activities in the Netherlands have aggregated crops at the production system level (e.g. Van der Hilst et al., 2010; Kuhlman et al., 2013). This approach allows taking explicitly into account the crop rotation schemes and management practices conducted by farmers, such as field operations and required inputs. A typology of agricultural production systems and related aggregation of crops is presented in Table 2. This typology is based on LEI's statistical records on Dutch farm accounts. Adopting LEI's typology as a benchmark for crop aggregation allows developing a modelling framework that is able to consistently link spatial patterns of agricultural activities with economic data on gross revenues and production costs of agricultural production (see Section 3). Figure 1 provides a representation of BRP dataset aggregated at production system level for the whole country.

Table 2: Crop aggregation and related typology of production systems

Crop type	**Production system**
Grassland for agricultural production, Maize	Dairy farming
Potatoes, Beets, Grains, Onions, Fallow	Arable farming
Legumes, Vegetables, Horticultural seeds	Open-field vegetable farming
Tree fruits, Berries	Fruit growing
Flower bulbs , Flowers	Flower growing
Tree nursery, Perennials	Tree nursery

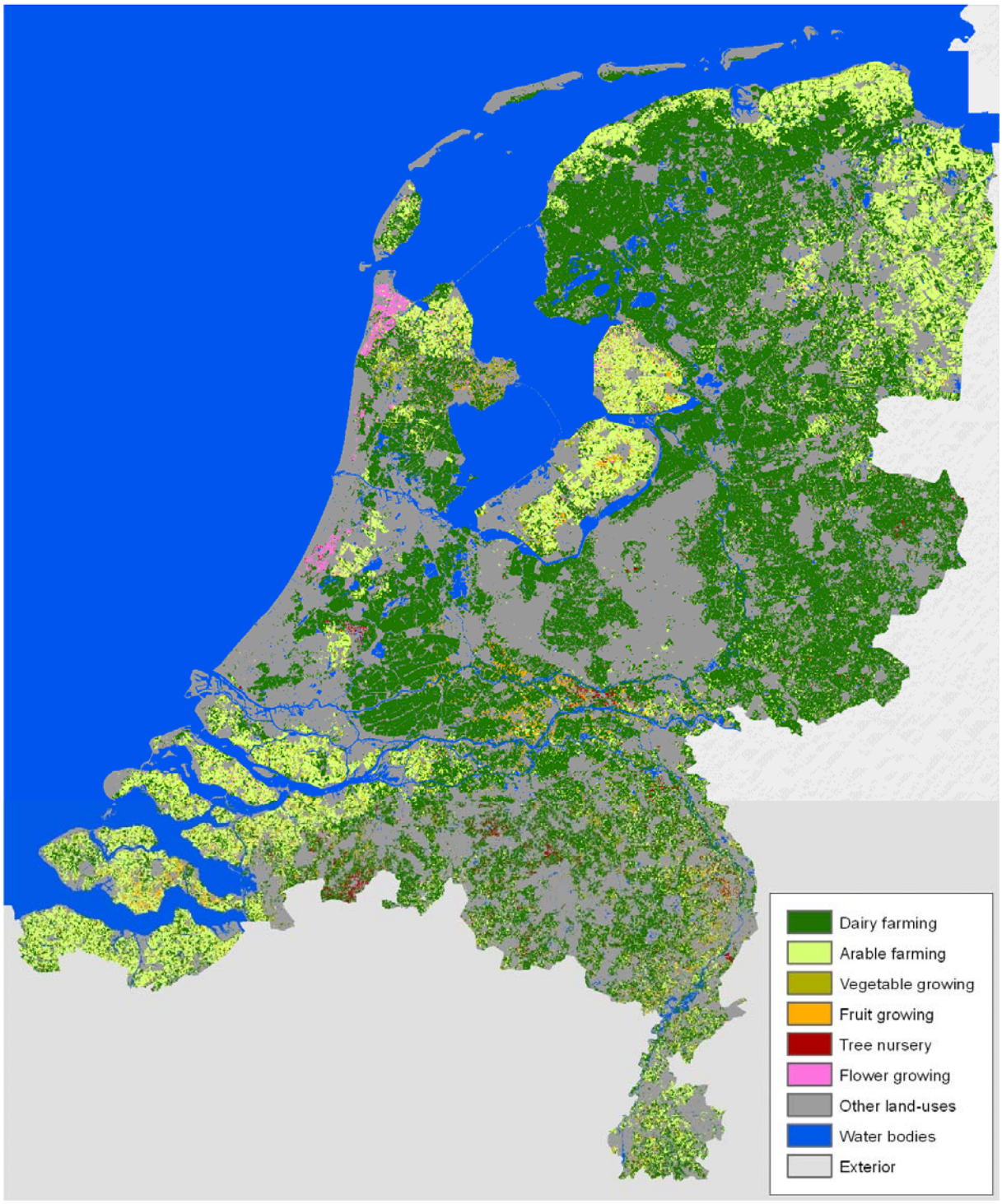

Figure 1: Spatial patterns of the main types of agricultural land-use in 2012 based on BRP.

3. Net Present Value as a valuation method of agriculture suitability

Net present value (NPV) is a standard method used in capital budgeting to appraise long-term projects, by measuring discounted time series of expected cash inflows and outflows, while taking into account the time value of money. To be regarded as economically attractive, an investment should have a NPV greater than zero. When applying this method to land-use decision-making in agricultural production, NPV is determined in the following way:

$$\mathrm{NPV_{c,i}} = \int_{t=0}^{\infty} (\mathrm{R_{c,i,t}} - \mathrm{C_{c,i,t}}) \exp(-\mathrm{st})\, \mathrm{dt}$$

where $NPV_{c,i}$ is the net present value of production system *i* in land parcel *c*, *t* is time, $R_{c,i,t}$ and $C_{c,i,t}$ are respectively the gross revenues and total costs of production system *i* in land parcel *c* and $s=ln(1+r)$, with *r* being the discount rate. This equation can be discretised in yearly time steps as follows:

$$\mathrm{NPV_{c,i}} = -\mathrm{Inv_{c,i}} + \sum_{y=0}^{n} \frac{\mathrm{R_{c,i,y}} - \mathrm{C_{c,i,y}}}{(1+\mathrm{r})^{y}}$$

where $Inv_{c,i}$ are the specific initial investment costs (e.g. land purchasing costs, new machinery, buildings and facilities) of production system *i*, $R_{c,i,y}$ and $C_{c,i,y}$ are respectively the yearly gross output and total costs of production system *i* in land parcel *c* in year *y*, *r* is the discount rate and *n* is the lifetime of the project. The yearly costs related to crop production include six main categories of expenses: field operation costs (contractor, machinery, labour and fuel costs), input costs (seeds, fertilizers and pesticides), fixed costs (insurance, soil sample assessment, etc.), storing costs and transportation costs:

$$\mathrm{C_{c,i,y}} = \sum_{p=1}^{n} \%\mathrm{p} * \left[\mathrm{FOC_{p,y}} + \mathrm{IC_{p,y}} + \mathrm{FC_{p,y}} + \mathrm{Y_{c,p,y}} * (\mathrm{SC_{p,y}} + \mathrm{TC_{p}} * \mathrm{d_{c,p}})\right]$$

where:

$C_{c,i,y}$ are the total costs resulting from production system *i* in cell *c* in year *y* (€/ha);

p is a product generated by production system *i*;

n are the number of products and co-products generated by production system *i*;

%p is the share of product *p* in crop rotation system of production system *i*;

$FOC_{p,y}$ are the field operation costs (€/ha);

$IC_{p,y}$ are the input costs (€/ha);

$FC_{p,y}$ are the fixed costs (€/ha);

$Y_{c,p,y}$ is the yield of product *p* in cell *c* in year *y* (ton/ha);

$SC_{p,y}$ are the storing costs of product *p* in year *y* (€/ton);

TC_p are the specific transportation costs of product *p* (€/ton.km);

$d_{c,p}$ is the distance to nearest market of product *p* (km).

The gross revenues are derived from selling products and subsidies on production (either per unit of production or per unit of land). Services and amenities that are explicitly monetised can also be taken into account (e.g. subsidies to farmers for providing environmental services, maintaining landscape, etc). Gross revenues are strongly related to local biophysical characteristics and calculated as follows:

$$R_{c,i,y} = SL_{c,i,y} + \sum_{p=1}^{n} \%p * \left[Y_{c,p} * (P_{p,y} + SP_{p,y})\right]$$

where:

$R_{c,i,y}$ are the gross revenues derived from production system *i* in cell *c* in year y (€/ha);

$S_{i,y}$ are subsidies on production system *i* per unit of land parcel area in year *y* (€/ha);

$P_{p,y}$ is the price of product *p* in year *y* (€/ton);

$S_{p,y}$ are subsidies on product *p* in year *y* (€/ton).

The NPV method has proven to be a suitable approach to assess the economic performance of agricultural production systems in a spatially-explicit way (e.g. Van der Hilst et al., 2010; Diogo et al., 2012; Kuhlman et al., 2013; Diogo et al., forthcoming) and can be used as a measure of local suitability in Land Use Scanner in an utility-based modelling framework (Koomen et al., forthcoming).

4. Implementation valuation module in Land Use Scanner

Implementing the valuation module in Land Use Scanner essentially calls for defining all local suitability values in monetary terms. This implies that the values added to the various components that define land suitability are expressed in € / m^2. For agricultural land use we suggest that these follow the NPV approach described in Section 3 of this report. For other land-use types different methods can be applied that are described in more detail elsewhere (Koomen et al., forthcoming). The continuous or discrete allocation algorithms of the model than initiate an iterative approach that simulates a bidding process between competing land users (or, actually, land-use classes). Each use will try to get its total demand satisfied, but may be outbid by another category that derives higher benefits from the land. In a simplified way, the model thus mimics the land market. Thus, by connecting bid price based suitability definitions and a discrete choice theory-based algorithm, it is possible to describe the land market clearing process: a land seller compares alternative bids and sells to the actor with the highest bid, thus maximizing both revenue of sellers and utility of buyers (Martinez, 1992).

The exact specification of the local suitability definitions required for implementing the valuation module will depend on the specific characteristics of the Land Use Scanner configuration that will be selected for the *'Deltaplan Veenweidegebieden'* project. Two main approaches can be suggested for incorporating the NPV based definitions of agricultural land suitability in the model: including all relevant spatial components and associated prices and costs in explicit scripting in the model or preprocessing all relevant information in a geographical information system (e.g. ArcGIS). For the sake of transparency and traceability we strongly recommend including all relevant components as separate spatial data layers and referring to them in DMS script files. An example of this approach is provided in Annex 1.

VU University is happy to further assist in the exact specification of the valuation module when all relevant data sets have been collected and added to the Land Use Scanner configuration selected for this project.

References

Bartholomeus, R. (2013) Notitie project 'Actualisatie schadefuncties landbouw': Overzicht van doorgevoerde verbeteringen in fase 1. KWR, WUR, De Bakelse Stroom.

Brouwer, F. and Huinink, J. (2002) Opbrengstdervingspercentages voor combinaties van bodemtypen en grondwatertrappen: geactualiseerde HELP-tabellen en opbrangstdepressiekaarten. Alterra, Wageningen.

Diogo, V., Koomen, E., Van der Hilst, F. (2012) Second generation biofuel production in the Netherlands. Research Memorandum 2012-4. Vrije Universiteit Amsterdam.

Diogo, V., Van der Hilst, F., Van Eijck, J., Faaij, A., Verstegen, J., Hilbert, J., Carballo, S., Volante, J. (forthcoming) Combining empirical and theory-based land-use modelling approaches to assess economic potential of biofuel production avoiding iLUC: Argentina as a case study. Submitted to Renewable & Sustainable Energy Reviews.

Feddes, R., Raats, P. (2004) Parameterizing the soil–water–plant root system. In: Feddes, R., Rooij, G., Van Dam, J. (Eds.), Unsaturated-zone Modeling: Progress, Challenges, Applications Wageningen UR Frontis Series Wageningen: 95-141.

Fischer, G, Nachtergaele, F., Prieler, S., Teixeira, E., Tóth, G., Van Velthuizen, Verelst, L., Wiberg, D. (2012) Global Agro-Ecological Zones (GAEZ v3.0): Model Documentation. International Institute of Applied Systems Analysis, Laxenburg, Austria / Food and Agricultural Organization of the United Nations, Rome.

Hazeu, G., Schuiling, C., Dorland G., Oldengarm, J., Gijsbertse (2010) Landelijk Grondgebruiksbestand Nederland versie 6: Vervaardiging, nauwkeurigheid en gebruik. Alterra rapport 2012, Alterra, Wageningen.

Koomen, E., Diogo, V., Dekkers, J., Rietveld, P. (forthcoming) A utility-based, multi-sector framework for local scale land-use modelling. Submitted to Journal of Economic Geography.

Kroes, J., Supit, I. (2011) Impact analysis of drought, water excess and salinity on grass production in The Netherlands using historical and future climate data. Agriculture, Ecosystems and Environment 144: 370–381.

Kuhlman, T., Diogo, V., Koomen, E. (2013) Exploring the potential of reed as a bioenergy crop in the Netherlands. Biomass and Bioenergy 55: 41-52.

Martinez, F.J. (1992) The bid-choice land-use model: an integrated economic framework. Environment and Planning A, 24(6): 871-885.

Van Bakel, P., Van der Waal, B., De Haan, M., Spruyt, J., Evers, A. (2007) HELP-2005: Uitbreiding en actualisering van de help 2005 tabellen ten behoeve van het waternood-instrumentarium. STOWA-rapport 2007-13, Utrecht.

Van der Hilst, F., Dornburg, V., Sanders, J., Elbersen, B., Van Dam, J., Faaij, A. (2010) Potential, spatial distribution and economic performance of regional biomass chains: The North of the Netherlands as example. Agricultural Systems 103(7): 403-417.

Van Velthuizen, H., Huddleston, B., Fischer, G., Salvatore, M., Ataman, E., Nachtergaele, F., Zanetti, M.., Bloise, M., Antonicelli, A., Bel, J., De Liddo, A., De Salvo, P., Franceschini, G. (2007) Mapping biophysical factors that influence agricultural production and rural vulnerability. Environmental and Natural Resources Series 11. International Institute of Applied Systems Analysis, Laxenburg, Austria / Food and Agricultural Organization of the United Nations, Rome.

Annex 1. Suggested approach to include NPV definitions in Land Use Scanner

This annex describes how the NPV approach can be implemented in Land Use scanner. The specification of NPV for arable farming is given as an example. Firstly, the share on the rotation scheme, production costs, gross revenues and net revenues are specified for each crop according to soil type. The calculation of these attributes for seed potatoes is shown below.

```
container Arable_farming
  {
  container seed_potatoes
      {
      attribute<ratio> rotation(rdc_100lu):
      Expr = "switch("
             "case( Present/Validation/Bodem_HELP >= value (1, BodemKlasse14k) &&
             Present/Validation/Bodem_HELP <= value (5, BodemKlasse14k), value
             (0.135, ratio)),"
             "case( Present/Validation/Bodem_HELP >= value (6, BodemKlasse14k) &&
             Present/Validation/Bodem_HELP <= value (14, BodemKlasse14k), value
             (0.041, ratio)),"
             "value ( 0.0, ratio))";
      attribute<EUR_ha> production_costs(rdc_100lu):
      Expr = "switch("
             "case( Present/Validation/Bodem_HELP >= value (1, BodemKlasse14k) &&
             Present/Validation/Bodem_HELP <= value (5, BodemKlasse14k), value
             (5111.6, EUR_ha)),"
             "case( Present/Validation/Bodem_HELP >= value (6, BodemKlasse14k) &&
             Present/Validation/Bodem_HELP <= value (14, BodemKlasse14k), value
             (4229.7, EUR_ha)), value (0.0, EUR_ha))";
      attribute<EUR_ha> gross_revenues(rdc_100lu):
      Expr = "switch("
             "case( Present/Validation/Bodem_HELP >= value (1, BodemKlasse14k) &&
             Present/Validation/Bodem_HELP <= value (5, BodemKlasse14k),
             value(9474.9, Eur_ha) * (value (1.0, ratio) -
             (Present/Validation/Agriculture/yr_potatoes / Float32(100.0)))),"
             "case( Present/Validation/Bodem_HELP >= value (6, BodemKlasse14k) &&
             Present/Validation/Bodem_HELP <= value (14, BodemKlasse14k),
             value(8449.7, Eur_ha) * (value (1.0, ratio) -
             (Present/Validation/Agriculture/yr_potatoes / Float32(100.0)))), value
             (0.0, EUR_ha))";
      attribute<EUR_ha> net_revenues(rdc_100lu):
             Expr = "rotation * (gross_revenues - production_costs )";
       }
  }
```

These attributes are calculated in a similar way for all other crops that are part of the production system. Subsequently the NPV is calculated, taking into account the aggregated annual economic performance of the system, the capital recovery factor (determined according to assumed discount rate and lifetime). In this specification, it also assumed that changes in production system involve initial investment costs such as conversion costs (e.g. land clearing, investment on new machinery and/or facilities) and land acquisition costs. Land acquisition costs are used as a proxy for farmer specialization, implying that a change of production system involves a change of the type of farmer that manages the land.

```
container Economic_performance
   {
       attribute<EUR_ha> net_revenues (rdc_100lu):
              Expr = "seed_potatoes/net_revenues + ware_potatoes/net_revenues”
              “+ starch_potatoes/net_revenues + sugarbeet/net_revenues +"
              "+ onions/net_revenues + winter_barley/net_revenues “
              “+ summer_barley/net_revenues + winter_wheat/net_revenues”
              “ + summer_wheat/net_revenues”;
       attribute<EUR_ha> land_costs (rdc_100lu):
              Expr =
              ”iif(Present/landuse/ggAgri_Model_2007/gg_Hectare/Arable_farming >
              value (0.0, ggHa), value (0, EUR_ha) , value(45525, EUR_ha))";
       attribute<EUR_ha> conversion_costs (rdc_100lu):
              Expr =
              "iif(Present/landuse/ggAgri_Model_2007/gg_Hectare/Arable_farming  >
              value (0.0, ggHa), value (0, EUR_ha) , value(7257, EUR_ha))";
   }
container NPV_ha
   {
       parameter<Float32> discount_rate:
              Expr = "value (0.055, Float32)";
       parameter<Float32> lifetime:
              Expr = "value (20.0, Float32)";
       parameter<Float32> capital_recovery_factor:
              Expr = "discount_rate / (value (1.0, Float32) - (value (1.0, Float32)"
              “+ discount_rate)^(lifetime))";
       attribute<EUR_ha> Arable_farming(rdc_100lu):
              Expr =
              "(Production_systems/Arable_farming/Economic_performance/net_revenues”
              “/ capital_recovery_factor)"
              "- Production_systems/Arable_farming/Economic_performance/land_costs”
              “- Production_systems/Arable_farming/Economic_performance/conversion_costs";
   }
```