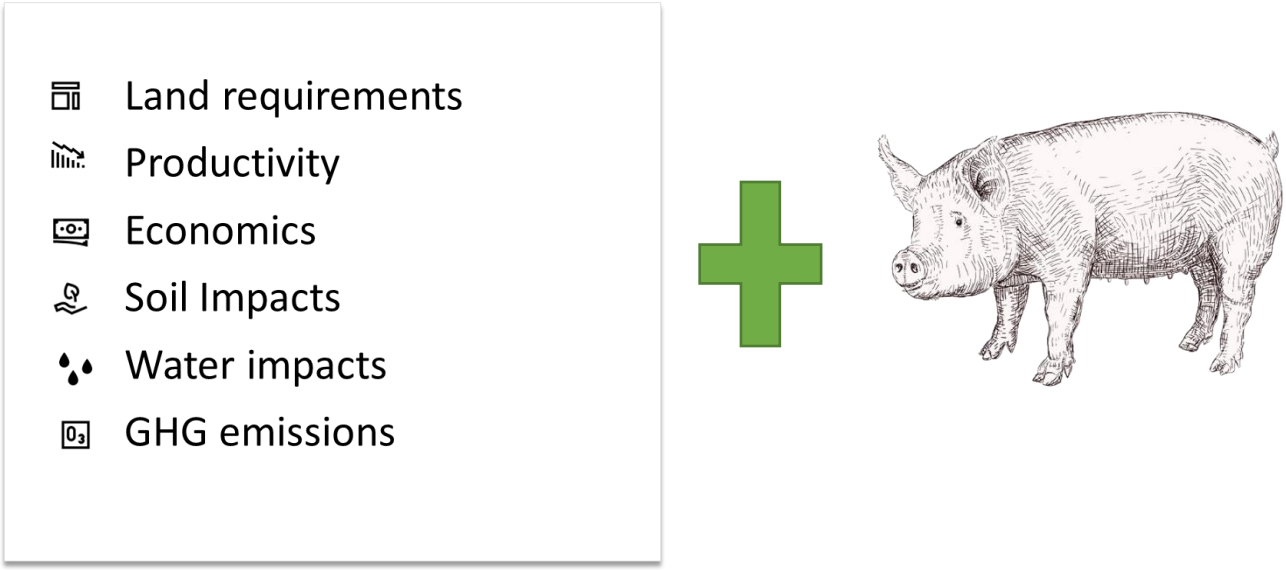
Report on refinements of CLEANED X Versions 2.0.1



Jessica Mukiri, An Notenbaert, Rein Van der Hoek

Alliance of Bioversity International and CIAT(ABC) Africa hub, Nairobi, Kenya

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CGIAR RESEARCH PROGRAM ON Livestock

Introduction

The Livestock CRP has undertaken a three-year investment that aims to integrate all key livestock interventions (feed, health, genetics, markets) into one core project in its priority countries (Ethiopia, Tanzania, Uganda and Vietnam). These core projects will support integrated delivery of already-identified 'best bet' interventions across the flagship areas and associated cross-cutting themes.

The Livestock & Environment flagship of the Livestock CRP has clear objectives of identifying environmental challenges contributed by livestock as well as providing baskets of options to diverse groups of stakeholders to ensure all livestock production is done as sustainably as possible. This is done through a number of scientific approaches. Ex-ante modelling is one of the approaches used. It allows to assess potential impacts of a variety of future livestock practices. It is a relatively fast and cheap way to allow the consideration of possible environmental impacts associated with the introduction of new technologies or farming systems.

CLEANED-X (link) is a tool that was designed by CIAT to carry out such an ex-ante environmental impact assessment. It allows users to explore multiple impacts of developing livestock value chains. It quantifies environmental footprints of different livestock productions systems in terms of:

- Land requirement for feed production (ha, ha/kg product)
- GHG emissions and carbon accumulation (absolute, per ha, per kg product, per protein)
- Soil health (Erosion, NUE, % area leached, % area mined)
- Water use (absolute, per ha, per kg product, per protein)
- Economics: simple Cost/Benefit, Net Present Value and Internal Rate of Return calculations for intervention scenarios

Model refinements

The first and second versions of the CLEANED-X model were focused on ruminants (cattle, goats and sheep) and extensively tested and applied in East-Africa cattle systems. As we are expanding the applications to, amongst others, the pig VC in Uganda, multi-species farming systems in Vietnam and silvopastoral systems in Latin-America, there was therefore an immediate need to add a pig and silvo-pastoral component to the model. In addition to that, ILRI developed CLEANED versions for Burkina Faso, Tanzania and Ethiopia, CLEANED-R, which are programmed in R. We identified some important differences between the two existing tools and decided to work on a new version of CLEANED (CLEANED-eXtRa) that draws on the strengths of both current tools. The following sections provide a few more details about the progress made with these new modules and move towards a new CLEANED version.

Pig parameter and calculation additions

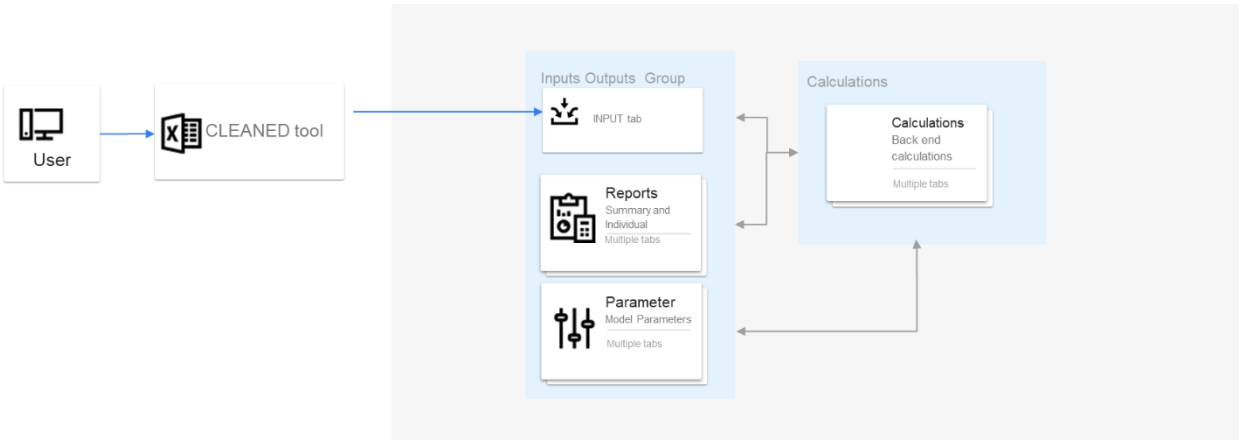


Figure 1 Architecture of CLEANED

CLEANED model architecture can be seen in Figure 1. To include the pig components, modifications were needed in the input sheet, parameters, calculations and reports. The next sections give an overview of what was added on to the model.

Input Sheet

The input sheet is key for the user to key important information that is needed for assessment. In the new model pig categories have been added to describe the herd composition, movement, and feed basket see Figure 2 (areas highlighted in yellow are the additions).

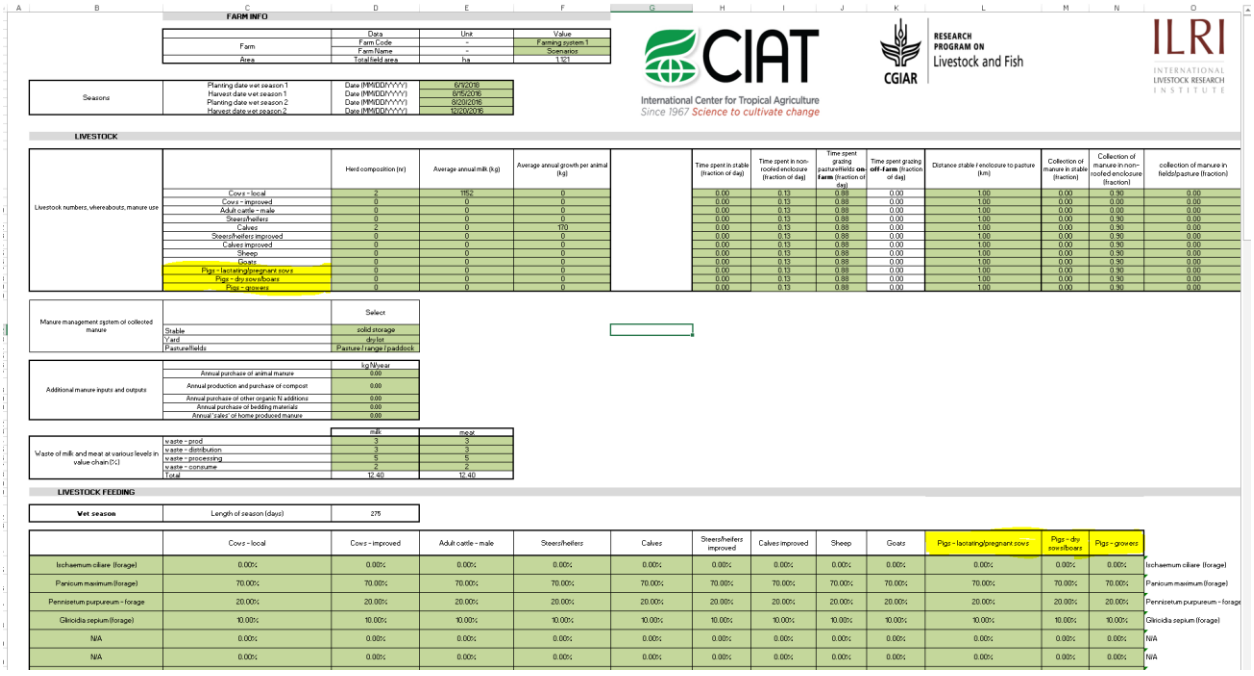


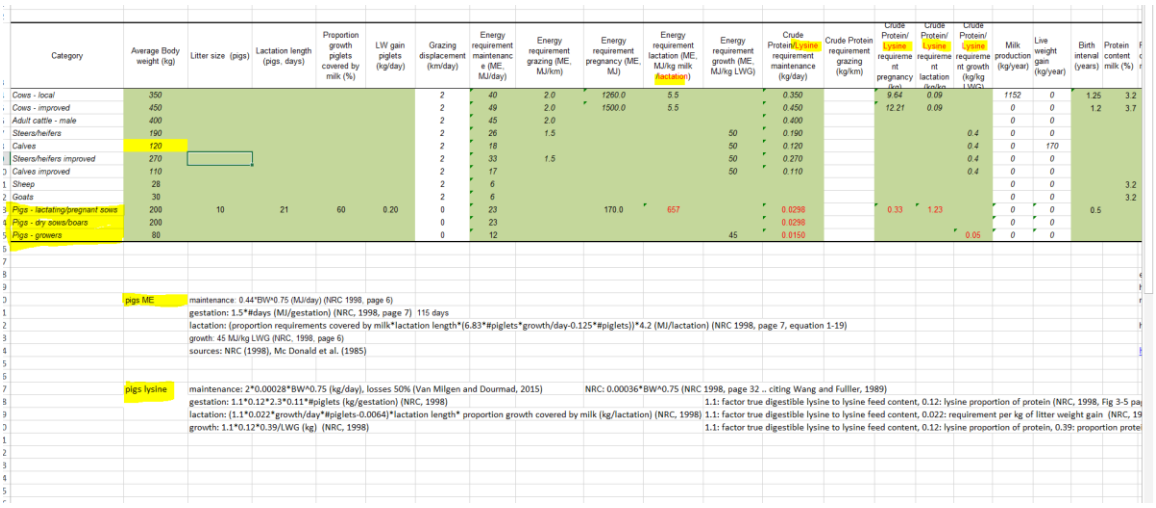
Figure 2 Addition of pigs in the input sheet on livestock and feeding sections

Livestock parameter Sheet

Livestock parameters are important when parametrizing the model to reflect the context, country and region for which the model is being used. In CLEANED this includes parameters such as live weight and milk production, which will impact energy and protein requirements of livestock, Figure 3.

For pigs the following additional parameters are required:

- Litter size
- Lactation length
- Proportion of piglet growth covered by milk
- LW gain piglets
- Lysine requirements



Category	Average Body weight (kg)	Litter size (pigs)	Lactation length (pigs, days)	Proportion growth piglets covered by milk (%)	LW gain piglets (kg/day)	Grazing displacement (km/day)	Energy requirement maintenance (ME, MJ/day)	Energy requirement grazing (ME, MJ/km)	Energy requirement pregnancy (ME, MJ)	Energy requirement lactation (ME, MJ/kg milk /lactation)	Energy requirement growth (ME, MJ/kg LWG)	Crude Protein/Lysine requirement maintenance (kg/day)	Crude Protein requirement grazing (kg/km)	Crude Protein/ Lysine requirement pregnancy (kg/	Crude Protein/ Lysine requirement lactation (kg/	Crude Protein/ Lysine requirement growth (kg/kg LWG)	Milk production (kg/year)	Live weight gain (kg/year)	Birth interval (years)	Protein content milk (%)
Cows - local	350					2	40	2.0	1260.0	5.5		0.350		9.64	0.09		1152	0	1.25	3.2
Cows - improved	450					2	49	2.0	1500.0	5.5		0.450		12.21	0.09		0	0	1.2	3.7
Adult cattle - male	400					2	45	2.0				0.400					0	0		
Steers/heifers	190					2	26	1.5			50	0.190				0.4	0	0		
Calves	120					2	18				50	0.120				0.4	0	170		
Steers/heifers improved	270					2	33	1.5			50	0.270				0.4	0	0		
Calves improved	110					2	17				50	0.110				0.4	0	0		
Sheep	28					2	6										0	0		3.2
Goats	30					2	6										0	0		3.2
Pigs - lactating/pregnant sows	200	10	21	60	0.20	0	23		170.0	657		0.0298		0.33	1.23		0	0	0.5	
Pigs - dry sows/boars	200					0	23					0.0298					0	0		
Pigs - growers	80					0	12				45	0.0150				0.05	0	0		

pigs ME	maintenance: 0.44*BW^0.75 (MJ/day) (NRC 1998, page 6)
	gestation: 1.5*#days (MJ/gestation) (NRC, 1998, page 7) 115 days
	lactation: (proportion requirements covered by milk*lactation length*(6.83*#piglets*growth/day-0.125*#piglets))*4.2 (MJ/lactation) (NRC 1998, page 7, equation 1-19)
	growth: 45 MJ/kg LWG (NRC, 1998, page 6)
	sources: NRC (1998), Mc Donald et al. (1985)
pigs lysine	maintenance: 2*0.00028*BW^0.75 (kg/day), losses 50% (Van Milgen and Dourmad, 2015) NRC: 0.00036*BW^0.75 (NRC 1998, page 32 .. citing Wang and Fuller, 1989)
	gestation: 1.1*0.12*2.3*0.11*#piglets (kg/gestation) (NRC, 1998) 1.1: factor true digestible lysine to lysine feed content, 0.12: lysine proportion of protein (NRC, 1998, Fig 3-5 pa
	lactation: (1.1*0.022*growth/day*#piglets-0.0064)*lactation length* proportion growth covered by milk (kg/lactation) (NRC, 1998) 1.1: factor true digestible lysine to lysine feed content, 0.022: requirement per kg of litter weight gain (NRC, 19
	growth: 1.1*0.12*0.39/LWG (kg) (NRC, 1998) 1.1: factor true digestible lysine to lysine feed content, 0.12: lysine proportion of protein, 0.39: proportion protei

Figure 3 Additional livestock parameters needed for pigs

Feed Calculations Sheet

All the calculations used in the CLEANED model have been documented[1].Below are the additional calculations added within the model to account for pigs.

Additional ME requirement calculations for pigs:

$$ME_{daily_i} = \sum ME_{m_i} + \ ME_{p_i} * \ ME_{la_i} + ME_{g_i}$$

[1] Notenbaert A; **Mukiri J**; van der Hoek R; Paul B; Koge J;Birnholz, C. (2019). CLEANED X-Version 2.0. 1. https://doi.org/10.7910/DVN/G0G8I , Harvard Dataverse, V1

$$ME_{m_i} = 0.44 * \text{ Metabolic Weight } (LWi)^{0.75}$$

$$ME_{p_i} = 1.5 * GP$$

$$ME_{la_i} = PM * LL * (78.7 * LS * DGP - 0.525 * LS)$$

$$ME_{g_i} = GrowReqi * LWG_i$$

Where i indicates the different animal categories and j the different seasons.
$\boldsymbol{ME_{daily\,i}}$ is daily energy requirement for animal i
$\boldsymbol{ME_{m\_i}}$ is the daily energy requirement for maintenance.
LWi is Live Weight for animal category I (expressed in kg). This found in the Livestock parameters.
$\boldsymbol{ME_{p\_i}}$ is the total energy requirement for pregnancy
GP is gestation period. This is found in the Livestock parameter sheet (115 days)
$\boldsymbol{ME_{la\_i}}$ is the total energy requirements for lactation.
PM is proportion of piglet growth covered by milk. This is found in the Livestock parameter sheet.
LL is lactation length. This is found in the Livestock parameter sheet.
LS is litter size. This is found in the Livestock parameter sheet.
DGP is daily growth of piglets. This is found in the Livestock parameter sheet.
$\boldsymbol{ME_{g\_i}}$ is the total energy requirement for growth
GrowReqi is the energy requirement for growing. This is expressed in MJ/kg LWG and is found in the Livestock parameters.
LWG$_i$ is the annual Live Weight gain for animal category i. This is user input.

Additional protein (lysine) requirement calculations for pigs:
The protein requirement of pigs is expressed as lysine, and we assume that pig protein contains 12% of lysine[2] .To calculate protein requirements, we assume that the protein in feed suitable for pigs contains 4% lysine.

$$LYS_{daily_i} = \sum LYS_{m_i} + \ LYS_{p_i} + \ LYS_{la_i} + LYS_{g_i}$$
$$LYS_{m_i} = 0.00056 * LW\text{^}0.75$$
$$LYS_{p_i} = 1.1 * 0.12 * 2.3 * 0.11 * \text{LS}$$

$$LYS_{la_i} = (1.1 * 0.022 * \text{DGP} * \text{LS} - 0.0064) * \text{LL} * \text{ PM}$$

$$CP_{g_i} = 1.1 * 0.12 * 0.39/\text{LWG}$$

$\boldsymbol{LYS_{daily\,i}}$ is daily lysine requirement for animal i

$\boldsymbol{CP_{m\_i}}$ is the total protein requirement for maintenance

[2] NRC (National Research Council) 1998. Nutrient Requirements of Swine. Tenth Revised Edition. National Academic Press, Washington, D.C. 20418 USA. Fig 3-5 page 35

LW is Live Weight in kg. This found in the Livestock parameter and is a user input.
$\boldsymbol{LYS_{p\_i}}$ is the total lysine requirement for pregnancy
1.1: factor true digestible lysine to lysine feed content
0.12: lysine proportion of protein (NRC, 1998, Fig 3-5 page 35)
2.3: weight gain per foetus in kg
0.11: protein content weight gain per foetus (NRC, 1998, page 37)
LS is litter size. This is found in the Livestock parameter sheet.
$\boldsymbol{LYS_{la\_i}}$ is the total lysine requirements for lactation
PM is proportion of piglet growth covered by milk. This is found in the Livestock parameter sheet.
LL is lactation length in days. This is found in the Livestock parameter sheet.
DGP is daily growth of piglets. This is found in the Livestock parameter sheet.
0.022: requirement per kg of litter weight gain (NRC, 1998, page 39)
0.0064: contribution sow (NRC, 1998, page 40)
$\boldsymbol{LYS_{g\_i}}$ is the total lysine requirement for growth
0.39: proportion protein in LW gain
LWG is Live Weight Gain. This is an input parameter.

Silvo-pastoral module

The silvopastoral component is added as a separate sheet ("Trees-Carbon")Figure 4 . The input variables are total area (usually derived from the Land sheet), number of trees per ha per category (e.g., leguminous, non-leguminous), number of years of tree growth, average diameter at breast height (DBH) in year 0, average DBH in year N and C-content of biomass.
The annual biomass per tree is calculated with the following formula[3]:

Leguminous trees:

$$BM_{year0} = 0.294 * DBH_{year0} \text{ ^ } 2.269$$

Non-leguminous trees:

$$BM_{year0} = EXP\ (-1.996 + 2.32 * LN\ (DBH_{year0}))$$

BM_{year0} is biomass in kg, year 0
DBH_{year0} is average diameter at breast height in cm, year 0

Leguminous trees:

$$BM_{year\_n} = 0.294 * DBH_{year\_n} \text{ ^ } 2.269$$

Non-leguminous trees:

$$BM_{year\_n} = EXP\ (-1.996 + 2.32 * LN\ (DBH_{year\_n}))$$

[3] BROWN, S. 1997. Estimating biomass and biomass change of tropical forests: A primer. Food and Agriculture Organization, Roma. (UN FAO Forestry Paper; no. 134).

$BM_{year\ n}$ is biomass in kg, year n
$DBH_{year\ n}$ is average diameter at breast height in cm, year n

The above-ground biomass increase is calculated as follows:

$$BMI = BM_{year\_n} - BM_{year0}$$

BMI above-ground biomass increase (kg)

The above-ground Carbon-increase (accumulation) is calculated as follows:

$$Cl_{ag} = BMI * 0.48$$

Cl_{ag} is Above-ground Carbon increase
0.48 is average carbon content of biomass

The total Carbon-increase:

$$Cltot = Cl_{ag} + 0.25 * Cl_{ag}$$

0.25 is average proportion root biomass of above-ground biomass

tree type	area (ha)	nb trees per ha	nb trees total	years	DBH year 0	DBH increase per year	DBH year N	Biomass year 0 per tree	Biomass year N per tree	Biomass increase total (t)	Biomass increase (t/year)	C-content Biomass	C-increase (t/year)	CO2e-increase (t/year)	C-increase SOC (t/year)	CO2e-increase SOC (t/year)	C-increase total (t/year)	CO2e-increase total (t/year)
legume	1.00	200	200	12	3	1.25	18	1.74	111.01	21.86	1.82	0.48	0.87	3.21	0.22	0.80	1.09	4.01
other	1.00	7	7	12	52	2	76	1301.00	3137.88	12.86	1.07	0.48	0.51	1.89	0.13	0.47	0.64	2.36
other	1.00	30	30	12	26	2	50	260.55	1187.84	27.82	2.32	0.48	1.11	4.08	0.28	1.02	1.39	5.10
other	1.00	40	40	12	13	2	37	52.18	590.71	21.54	1.80	0.48	0.86	3.16	0.22	0.79	1.08	3.95
other	0.00	10	0	12	20	2	44	141.75	883.00	0.00	0.00	0.48	0.00	0.00	0.00	0.00	0.00	0.00
			0				0	0.00	0.00	0.00	0.00	0.48	0.00	0.00	0.00	0.00	0.00	0.00
			0				0	0.00	0.00	0.00	0.00	0.48	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL								1757.22	5910.44	84.07	7.01		3.36	12.33	0.84	3.08	4.20	15.41

Gliricidia					**Other**				
year	DBH	Height	Volume	Biomass	year	DBH	Height	Volume	Biomass
1	1.25	0.7	0.0000	0.23	1	2	0.7	0.0001	0.68
2	2.5	1.4	0.0003	1.14	2	4	1.4	0.0009	3.39
3	3.75	2.1	0.0012	2.92	3	6	2.1	0.0030	8.68
4	5	2.8	0.0027	5.69	4	8	2.8	0.0070	16.92
5	6.25	3.5	0.0054	9.54	5	10	3.5	0.0137	28.39
6	7.5	4.2	0.0093	14.56	6	12	4.2	0.0237	43.34
7	8.75	4.9	0.0147	20.83	7	14	4.9	0.0377	61.97
8	10	5.6	0.0220	28.39	8	16	5.6	0.0563	84.47
9	11.25	6.3	0.0313	37.31	9	18	6.3	0.0801	111.01
10	12.5	7	0.0429	47.64	10	20	7	0.1099	141.75
11	13.75	7.7	0.0571	59.43	11	22	7.7	0.1463	176.84
12	15	8.4	0.0742	72.72	12	24	8.4	0.1899	216.39

Figure 4 Silvopastoral component in CLEANED

Way forward CLEANED-eXtRa

The CLEANED–X tool is currently in being merged with the CLEANED-R tool. Table 1 shows a comparison between the two models and which elements of both models will be incorporated in the newly merged CLEANED eXtRa.

Table 1 Comparison between CLEAND X and R

	CLEANED X	CLEANED R	To be adopted for CLEANED eXtRa
Overall	Flexible for users to be applied in another region	Needs a programmer's input to set up for a specific region	X's flexible approach
	Calculations set up for ruminants only	Calculations set up for ruminants only	add pig calculations
Inputs	Flexible feed basket composition / fully user-defined	one crop per pre-defined category - needs programmer to change this	Flexible feed basket
	Herd = user-defined	Herd descriptions are hard-coded; needs programmer to change	Flexible herd descriptions
Parameters	user-defined soil and climate parameters	Soil and climate parameters extracted from GIS layers (European soil dataset, Worldclim)	to be extracted from GIS layers
	user-defined yields and ET values (one value for the whole region)	Spatial variation as extracted from GIS layers	to be decided; maybe some kind of mix?
Calculations	economics	no economics	keep economics (though probably not important for priority country applications)
	nothing on biodiversity	"endangered species" if landuse change scenarios is being implemented	to be decided
	Land requirement - absolute increase/decrease calculated	land requirement increase is being compared with available crop land	to be decided

Merging of the tool will occur in 2020 and the process for merging the two tools includes:

- Standardize parameters
- Finalize R script
- Front end / user interface
- Testing and deployment of the application

Implementation plan

For CLEANED to be implemented in the four countries a number of activities will need to be conducted. The table below gives a tentative plan of the activities that need to be done for 2020 - 2021.

Deliverables/tasks 2020	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Planning and Admin tasks Q1												
CLEANED trainings preparation (Testing of CLEANED tools, CLEANED webinars, data and refresher to the program)												
CLEANED trainings Nairobi												
Planning and Admin tasks Q2												
Planning and Admin tasks Q3												
Planning and Admin tasks Q4												
CLEANED application backstopping - baseline runs 1st trip												
CLEANED application backstopping - scenario runs 2nd trip												
Intern supervision												
Deliverables/tasks 2021	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
CLEANED results and validation 3rd trip (2021)												
CLEANED Nairobi results (2021)												
Reports write up (2021)												