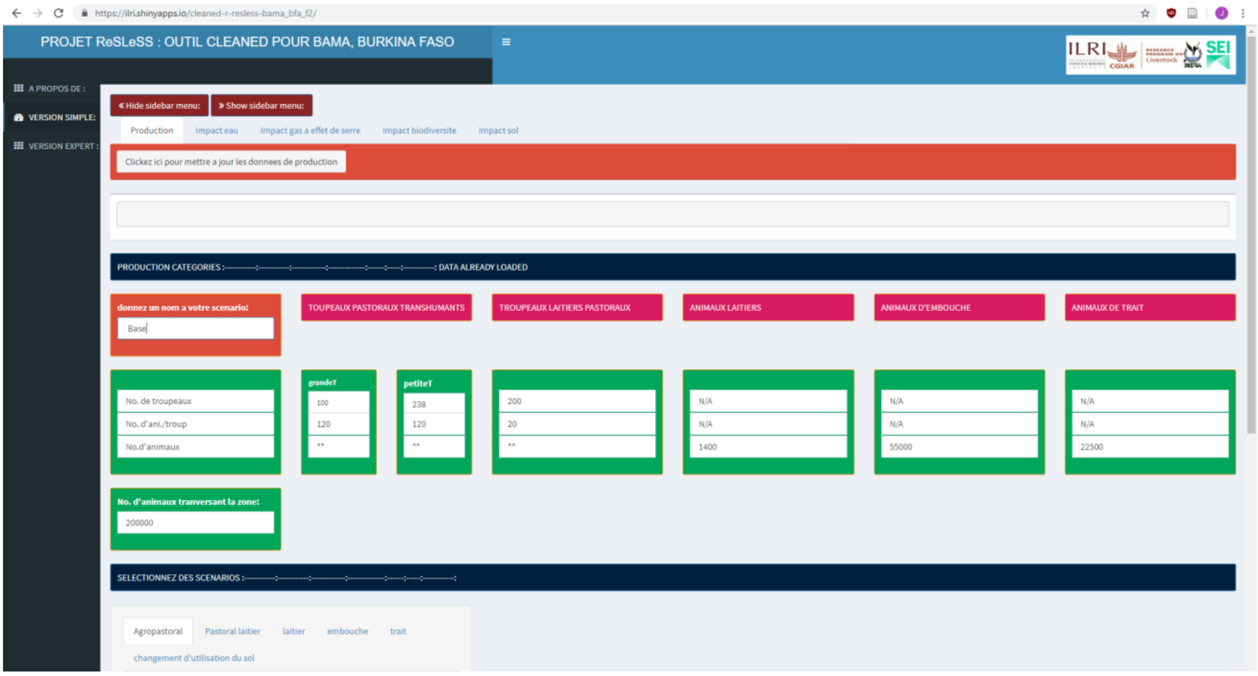
Sustainable Agricultural Intensification Research and Learning in Africa

The CLEANED R tool

Generic manual

June 2019



Prepared by SEI and FiBL on behalf of SAIRLA

Funded by: UKaid from the British people

Implemented by: and UNIVERSITY of GREENWICH NRI | Natural Resources Institute

The CLEANED R tool: Generic manual

June 2019

Authors:

Catherine Pfeifer[1], Joanne Morris[2], Jonathan Ensor[2]

[1] Research Institute for Organic Agriculture (FiBL), ex-International Livestock Research Institute (ILRI), Nairobi
[2] Stockholm Environment Institute (SEI), Department of Environment and Geography, University of York (UoY)

This project, 'Research and Learning for Sustainable Intensification of Smallholder Livestock Value Chains in Burkina Faso, Ethiopia and Tanzania' (ResLeSS), is part of the Sustainable Intensification of Agricultural Research and Learning in Africa (SAIRLA) Programme. It is led by the Stockholm Environment Institute (SEI), in collaboration with the International Livestock Research Institute (ILRI), Environment and Climate Research Center (ECRC) at the Policy Studies Institute (PSI), Institut de l'Environnement et de la Recherche Agricole (INERA) and Sokoine University of Agriculture (SUA). The project is working with the CGIAR Livestock CRP Country Coordinators, ICARDA in Ethiopia, and ILRI in Tanzania and Burkina Faso.

Funded by the United Kingdom Department of International Development (UK DFID), SAIRLA is a five-year programme (2015 to 2020) that seeks to generate evidence and design tools to enable governments, investors and other key actors to deliver more effective policies and investments in sustainable agricultural intensification (SAI) that strengthen the capacity of poorer farmers', especially women and youth, to access and benefit from SAI in Burkina Faso, Ethiopia, Ghana, Malawi, Tanzania and Zambia. The SAIRLA programme is managed by WYG International Ltd and the Natural Resources Institute, University of Greenwich.

This document was made possible with support from the UK Department for International Development. The contents are the responsibility of the producing organization and do not reflect the views of UK DFID, the British Government, WYG, nor the University of Greenwich - Natural Resources Institute.

Funded by: Managed by: and

The project thanks all donors and organizations who globally supported its work through their contributions to the CGIAR Trust Fund.

© 2019

This publication is licensed for use under the Creative Commons Attribution 4.0 International Licence. To view this licence, visit https://creativecommons.org/licenses/by/4.0.

Unless otherwise noted, you are free to share (copy and redistribute the material in any medium or format), adapt (remix, transform, and build upon the material) for any purpose, even commercially, under the following conditions:

ATTRIBUTION. The work must be attributed, but not in any way that suggests endorsement by the publisher or the author(s).

Contents

Acronyms

Acronym	
AFSIS	Africa Soil Information Service
CGIAR	Consultative Group on International Agricultural Research
CLEANED	Comprehensive Livestock Environmental Assessment for improved Nutrition, a secured Environment and sustainable Development
CO2	Carbon dioxide
CO2eq	Carbon dioxide equivalent
CRP	CGIAR Research Program
CSI	CGIAR Consortium for Spatial Information
DFID	UK Department for International Development
DHS	Demographic Health Survey
ECRC/PSI	Environment and Climate Research Center (ECRC) at Policy Studies Institute (PSI)
ET	Evapotranspiration
FiBL	Research Institute for Organic Agriculture
GAEZ	Global Agro-ecological Zones
GB	Gigabyte
GHG	Greenhouse Gas
GIS	Geographic Information System
GRAF	Groupe de Recherche et d'Action sur le Foncier
ICARDA	International Center for Agricultural Research in the Dry Areas
ILRI	International Livestock Research Institute
INERA	Institut de l'Environnement et de la Recherche Agricole
IPCC	Intergovernmental Panel on Climate Change
IUCN	International Union for Conservation of Nature
kg	kilogram
km	kilometre
l/year	litres per year
MODIS	MODerate Resolution Imaging Spectroradiometer
NASA	National Aeronautics and Space Administration
NRI	Natural Resources Institute
OS	Operating System
RAM	Random Access Memory
ResLeSS	Research and Learning for Sustainable Intensification of Smallholder Livestock Value Chains
RUSLE	Revised Universal Soil Loss Equation
SAI	Sustainable Agricultural Intensification
SAIRLA	Sustainable Agricultural Intensification Research and Learning in Africa

SAIRLA

SEI	Stockholm Environment Institute
SERVIR	Sistema Regional de VIisualización y Monitoreo de MesoAmerica
SUA	Sokoine University of Agriculture
UK	United Kingdom
UN	United Nations
UNB	Université Nazi Boni de Bobo-Dioulasso
UoY	University of York

Executive Summary

CLEANED, the Comprehensive Livestock Environment Assessment for improved Nutrition, secured Environment and sustainable Development, was initiated as a framework to assess environmental impacts from rapidly evolving livestock value chains in the developing world. The CLEANED R tool is an evolution of this, offering a spatially explicit tool for calculating impacts at landscape scale. This report provides a general documentation of the CLEANED R tool, explains how the tool is set up for a particular study area and describes what steps would be needed to adjust the tool for a new study area.

1 Introduction

CLEANED, the Comprehensive Livestock Environment Assessment for improved Nutrition, secured Environment and sustainable Development, was initiated as a framework to assess environmental impacts from rapidly evolving livestock value chains in the developing world (Notenbaert et al., 2016, 2014). Two different implementations of the framework have been developed: i) the *CLEANED X – Version 1.0.1* tool in Microsoft Excel, calculating impacts at the farm scale (Notenbaert et al., 2018); and ii) the *CLEANED R* tool in R (R Core Team, 2017), a spatially explicit tool calculating impacts at landscape scale (Pfeifer, 2019).

This report provides a general documentation of the CLEANED R tool, explains how the tool is set up for a particular study area and describes what steps would be needed to adjust the tool for a new study area. This documentation is generic. For every CLEANED R tool that has already been set up, i.e. for each study area the tool was adjusted for, there is a site-specific report explaining how the procedures described in this report have been implemented concretely. The tool has been set up for Bama commune in Hauts-Bassins region, Burkina Faso (Pfeifer et al., 2018b), Lushoto district in Tanga region, Tanzania (Pfeifer et al., 2018c) and Atsbi woreda in Tigray, Ethiopia (Pfeifer et al., 2018a). For the DFID funded SAIRLA project[1], the CLEANED R tools were set up and used as a part of a computer assisted social learning process. There is a user guide describing the participatory process (Morris et al., 2019) and a report from the process run with each site-specific tool (Ensor et al., 2018; Pfeifer et al., 2018d, 2018e). Computer installation instructions for the existing standalone CLEANED R tools are also given in Section 4.

The CLEANED R tool is a quick and spatially explicit simulation tool that computes environmental impacts from livestock production. This means that it is quick to set up for a new area, and uses spatially disaggregated data as the input to the calculations so that the results, while relatively coarse, are better than when using average values for the study area. As such, it aims at balancing context specificity and speed of implementation. On the one hand, generic models are often available for any part of the globe after the first investment of time in developing the tool, but may be too general to support decision-making on the ground because they are not sufficiently context specific. This is particularly true for the African continent, which often is not comparable to the Western contexts for which these generic models were developed and parameterised. On the other hand, studies that collect their own context-specific data for one site give much more accurate results, but often need years to acquire and analyse the data, defying the need of policymakers to take immediate decisions. The principle of the CLEANED R tools is that they are designed to be developed for a new area within weeks and yet give results that are good enough to support policymakers in a context-specific manner. To achieve this, the tools make use of readily available data only, refining that secondary data with expert knowledge. The tools combine globally available medium and high resolution geographical data, i.e. data that are spatially disaggregated and therefore context specific, with expert information derived from key informant interviews and/or a participatory stakeholder workshop.

The CLEANED R tool is developed as part of the Transformation Game, a computer assisted multi-stakeholder participatory process. The Transformation Game aims at engaging decision makers in an area in a social learning process through which they learn about synergies and trade-offs in their particular context, with a view to developing an inclusive future vision for the livestock sector in their area. Decision makers are all agents who take decisions related to the livestock sectors and therefore this definition includes policymakers, as well as all players along the livestock value chain, including retailers, middlemen, and farmers.

A key reason for embedding the CLEANED R tool in the Transformation Game is that the CLEANED R tool does not provide answers. It provides information about potential changes in key environmental variables (water use, soil nitrogen balance, greenhouse gas emission, loss of habitat and land use) and meat and milk production. **It does not make the judgement about whether these changes are acceptable or not** because there are countless factors related to the socio-economic and biophysical context that influence what impact these changes might have. Therefore, the Transformation Game defers assessment and judgement of the information to a collection of interested and invested experts (the actors, local or other, who will be affected by or make decisions on the impacts).

[1] 'Research and learning for sustainable intensification of smallholder livestock value chains' (ResLeSS), https://sairla-africa.org/what-we-do/research/research-and-learning-for-sustainable-intensi%EF%AC%81cation-of-smallholder-livestock-value-chains-resless/; https://www.york.ac.uk/sei/projects/current-projects/resless/

2 Overview of the CLEANED R tool

2.1 Modules

The CLEANED R tool is a spatially explicit[2] simulation tool that estimates environmental impacts from the livestock sector. It computes water use, greenhouse gas emissions, habitat loss and nitrogen balance of a given area based on livestock production parameters that are defined by the user (Pfeifer et al., 2016). The tool at this stage only includes impacts that can be attributed to local livestock production within a study area (i.e. feed and animal production), and does not yet include the rest of the value chain[3]. This implies that it is not a life cycle analysis and that impacts occurring beyond meat and milk production and outside of the study area are not considered. This limitation is minor in those study areas for which CLEANED R has been adjusted because value chains are relatively short and most import of feed and fodder production is in the form of concentrates, which are generally agro-industrial by-products that would have been wasted otherwise and therefore represent a low environmental impact.

The tool consists of input (data processing steps), calculation (calculation modules) and output tables (on an R-Shiny interface) as represented in Figure 1. Input includes open-source GIS data (Table 1) and expert knowledge. The six calculation modules are: production and land allocation, water, greenhouse gas, biodiversity, nitrogen balance and land use change. Output tables and maps are produced in an R-Shiny interface, which is available both online and as a standalone tool that one can run offline on one's personal computer (see section 3 for links). These are explained in more detail in the following sub-sections.

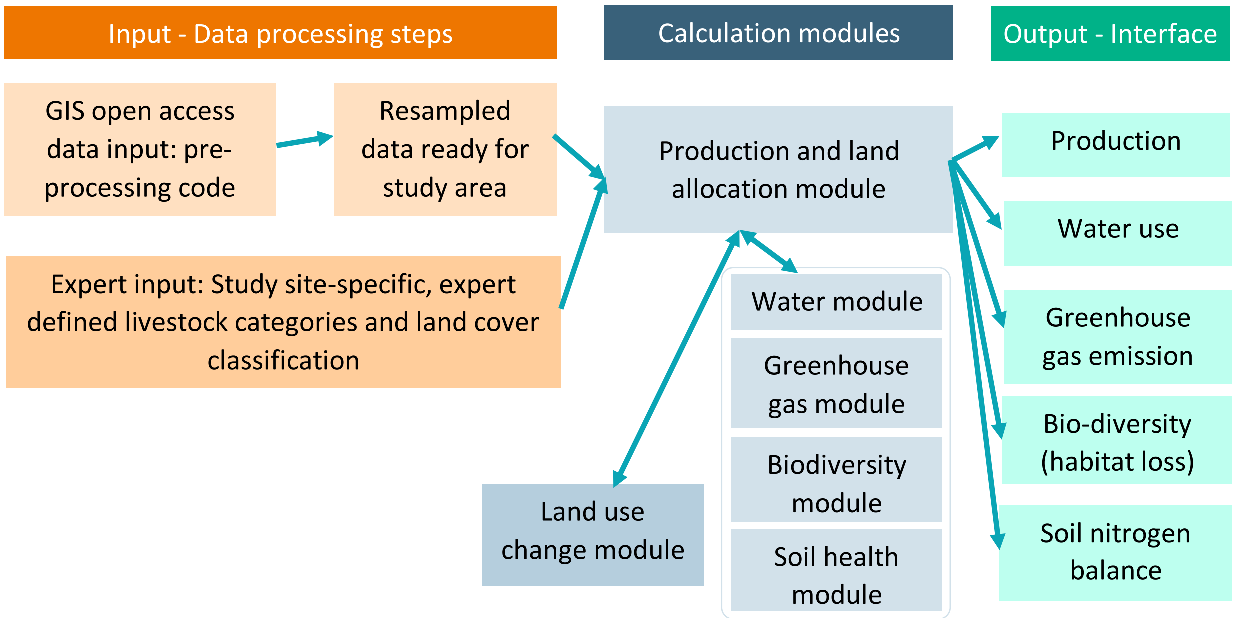


Figure 1: Graphical overview of the different modules in CLEANED R.

As the tool is spatially explicit, most parameters are extracted from a range of open-access spatial GIS layers, which are then utilized in the different calculation modules. Each module is built around equations or models that provide a simple, yet robust measure for that module, according to the literature available at the time of tool development. The trade-off of using simple equations is that some of the variability in the system is not captured, although being spatially explicit mitigates this. As such, the results are not perfect but they are good

[2] The tool is based on gridded spatial layers, basically digital maps that divide the study area into a grid, and give a value for each pixel of the grid. The pixel size for the tool is a 30 m x 30 m square. The tool calculates changes in environmental variables for each pixel to show variations in the environmental variables across the study landscape, based on landuse and variations in soil fertility and rainfall.
[3] "The livestock value chain can be defined as the full range of activities required to bring a product (e.g. live animals, meat, milk, eggs, leather, fibre, manure) to final consumers passing through the different phases of production, processing and delivery" (Rota and Sperandini, 2010; citing Kaplinsky and Morris, 2000).

enough to provide an indication to support critical discussion (Box 1). The equations or models used in each module and the GIS layers from which they draw data are listed in Table 1, with references.

Table 1: Overview of models and geographical data in the CLEANED R modules

Module	Equations or model used	GIS layers used
Production and land allocation	IPCC energy requirement per animal in each category (IPCC, 2006) Allocates the total energy to land cover based on crop and grazing land	Land cover (country specific, see CLEANED R Documentation for each study area, 30 m resolution[4]) Maize, legume and grass productivity (GAEZ, 5-arc minute resolution, about 10 km (Fischer et al., 2012))
Land use change	Grazing land is converted to cropland based on suitability (own computation see section 2.3.2)	Suitability for cropland (GAEZ, 5-arc minute resolution, about 10 km (Fischer et al., 2012)) Distance to existing cropland (computed from the land cover)
Water	Evapotranspiration of the biomass fed to livestock	Evapotranspiration for specific crops (GAEZ, 5-arc minute resolution, about 10 km (Fischer et al., 2012)) Rainfall (worldClim, 30 arc second resolution, about 1 km (Hijmans et al., 2005))
Greenhouse gas emissions	IPCC tier II computation (IPCC, 2006)	IPCC soil & climate layer (IPCC, 2006) Temperature (worldClim, 30 arc second resolution, about 1 km (Hijmans et al., 2005))
Biodiversity	IUCN red list allocated to land cover (IUCN, 2017)	Land cover
Soil health	Nitrogen balance (Smaling et al., 1993) including an erosion model (RUSLE)	Soil characteristics (soilgrids, previously AfSIS, 250 m resolution (Hengl et al., 2015)) Elevation (CSI, 90 m resolution (Jarvis et al., 2008)) Soil erosivity factor (Vrieling et al., 2010) Leaf Area Index (MODIS/NASA, 500 m resolution (Myneni et al., 2015))

Box 1: Health warning – how to use the outputs of the CLEANED R tool

Because CLEANED R makes use of these secondary data (Table 1), which are only qualitatively validated for the specific study area, the output for the study area should be taken and interpreted with caution. The absolute values[5] calculated by each module are neither perfect nor accurate environmental indicators. Yet, after running a scenario to change livestock production, when the calculated absolute value of these indicators is compared to the calculated absolute value of the base run (an approximation of the current situation), they provide an indication of how the environmental indicators might change. This indication of the direction and magnitude of change can help decision makers understand the dynamics that shape environmental impacts.

For example, CLEANED R might calculate a greenhouse gas emission of 2,000 CO_{2eq} / cow / year for the study area. This number is within the credible range of a cow's emissions according to published studies, assuming IPCC tier 2 computations are correct. However, if a cow from the study area were put in a gas chamber to measure its actual emissions, the true number would be different from 2,000. However, the *percentage change compared to the base run*, represents the realistic change for the study area. These relative change measures[6] are often good enough to develop appropriate policies or interventions.

[4] This means the pixel size is 30 m x 30 m.
[5] The actual magnitude of a numerical value or measurement, irrespective of its relation to other values (Google dictionary).
[6] Relative difference compared to the static reference value of the baseline, approximating the current situation when the tool was coded

2.2 Input - Data processing modules

The tool uses a combination of secondary data (open-access GIS spatial layers) combined with expert input.

2.2.1 GIS input data: pre-processing to resample data to the study area

The various GIS data layers have different resolutions (from 30 m to 10 km), and cover different geographic areas (from country to global extent). Therefore, before entering the CLEANED R modules, the GIS layers are first clipped to the study area boundaries, and then resampled to 30 m resolution to allow the calculation modules to use the layers correctly.

2.2.2 Expert input: study area specific characterization of CLEANED R

Each CLEANED R tool is tailored to its study area using expert input, allowing the tool to represent the specificity of the context and to be equipped to explore the major challenge for which the tool is applied. What this means is that for each study area, a completely new tool is developed, yet all study-area specific tools use the same logic, structure and modules described in Figure 1 and in the following sections. What differentiates the different tools are: i) the livestock categories used to represent the livestock herd in the study area; and ii) the classification of the land cover map.

2.2.2.1 *Livestock categories and their related feed baskets*

For every CLEANED R tool developed so far, relevant livestock categories were defined based on expert knowledge. For Bama, Burkina Faso, CLEANED R considered only cattle, split into quite detailed categories which allowed the tool to capture the pastoral cattle keeping using the language of the local people. For Lushoto, Tanzania, a dairy specific value chain was modelled, and different livestock breeds and management types were used to define the CLEANED R livestock categories. Finally for Atsbi, Ethiopia, livestock categories were defined to capture the opportunities from the master plan as well as the priorities from many donor programs focusing on the poorer share of the population by modelling both dairy and sheep.

Livestock categories describe groups of animals that have similar characteristics and management, particularly in terms of what they are fed. The categories are defined in CLEANED R, by the modeller in consultation with experts and literature available for the study area, with: i) live weight of an average animal in that category; ii) the average production of animal sourced food[7] that can be expected over a year from an animal in that category; iii) and how the animals in that category are fed. How the animals are fed is described by a feed basket reflecting what type and quantity of feed and forages are used. The feed and forages are very context specific, and therefore are different from one tool to another.

The modules compute production and environmental indicator values for each livestock category separately, and then aggregate these at the end to present absolute values for the landscape. This implies that recoding across the tool is necessary when each new livestock category is created, in order to ensure that the energy requirement for each species and each management practice is carried through the calculations correctly.

2.2.2.2 *Land cover*

Land cover is at the core of the Production and Land Allocation module as well as the Land Use Change module. Given that the SAIRLA study areas are relatively small, a resolution of 30 sq. meter is reasonable. The modeller, in consultation with experts and based on a land cover map validation from the reconnaissance tour, defines which land cover classes will be used by CLEANED R as cropland, grazing land or unsuitable for livestock feed production from the land cover map for the study area (see Land Use Change module for more detail). The study site specific CLEANED R Documentation reports describe this process (Pfeifer et al., 2018b, 2018c, 2018a).

At the beginning of the SAIRLA project, there was no existing land cover product for the whole of Africa at 30 m resolution. This implied that for each study site the Production and Land Allocation module and the Land

[7] Food that comes from animals, in the case of the livestock value chains represented in existing CLEANED R tools, this means meat and milk.

Use Change module had to be re-written in order to handle the different land cover categories for each map. Recently, more and more continental and global land cover products have been developed or are under development, with yet unknown level of accuracies, opening the door for a standardisation of the land cover related codes in CLEANED R, reducing the need for recoding.

2.3 Calculation modules

2.3.1 Production and land allocation module

The Production and Land Allocation module, as the name suggests, computes a measure of production and which land is used or required to support that production. The module calculates the total amount of animal sourced food produced, which is essentially user defined when setting the live-weight, meat or milk yield per year and the number of animals in the defined study area livestock population. The main task of the module is to then compute the total energy required by the animals to produce the defined amount of animal sourced products, and then calculate how much biomass is needed as feed to supply that energy. As the energy content of different types of feed varies, different feed baskets[8] will require different amounts of biomass to satisfy the same energy requirement. The module then compares the amount of biomass required with the biomass production in the area, according to local crop and grass yields, and therefore allocating biomass production for the livestock population to the land in the study area. As such, it computes the area required by the livestock population for feed production in terms of arable land and grazing land, as well as the total amount of each feed needed from the study area. The equations used for these computations are based mainly on IPCC tier 2 computations of energy use of the total livestock population, split by livestock categories, with the geographical layers summarized in Table 1. Basically, it computes a feed demand (as the weight of biomass needed for the defined livestock population in the study area) resulting from the number of animals in each category, the energy requirement in each category (based on live weight and activity), the feed basket for each category and the fresh weight of each feed and fodder in the model.

CLEANED R computes the biomass supply from the study area based on a land allocation model. CLEANED R separates feed and fodder into three categories:

1. Feed and fodder that comes from arable land (cereals, crop residue, planted fodder), in CLEANED R referred as cropland

2. Natural feed from grassland and shrublands used as pastures or cut-and carry ; in CLEANED R referred as grazing land

3. Agro-industrial by products such as bran or oil seed cakes (concentrates), which are not assigned to any land because they would be considered waste products.

The last group is not assigned to any land use, whereas the first two are allocated to land based on the land cover map and therefore are specific to each study site (see Land Use Change module for more detail). Most land cover maps have classes that link in a straightforward way to the two CLEANED R classes, perennial crop to the first category (cropland), and grazing land to the second category (grazing land). The main criteria used in assigning classes from the land cover map to the CLEANED R classes is how much biomass they provide to livestock. For example, classes like non-perennial crop are usually excluded from the cropland category, as crops such as sisal or sugar cane do not provide any residue for livestock to consume. In some areas, some of the arable land does not produce any crop residue for livestock and is a perennial crop or simply cannot be identified on the land cover map, for example tobacco. CLEANED R can only handle such croplands which cannot be identified on the land cover map by reducing them to total amount of land in an ad-hoc manner, implying that for every arable land pixel in the first CLEANED R land use category only a given percentage of the pixel is producing crop residue. A good practice is to do a land cover validation during the reconnaissance tour and land use categories to the CLEANED R land use categories based on local evidence.

[8] The combination of type and proportion of feeds used (e.g. 40% grass, 30% crop residues, 5% maize bran etc. up to sum up to 100%)

2.3.2 Land use change module

CLEANED R has a land use change module, that can convert any land into arable land, except land that has been excluded. Non-convertible land is study site specific but generally includes urban area, water, rock but also protected area based on the IUCN map of protected areas or the pastoral zones in Burkina Faso. CLEANED R assumes that there are no realistic scenarios in the developing world in which cropland is converted into grazing land that can be a source of natural feed and fodder (grazing or collecting natural grass to feed stabled animals).

The land use change module can be chosen when defining a new scenario with changes to production practices within categories, to change the amount and type of land available for producing feed, before running the environmental impact modules (water, GHG, biodiversity and soil).

Two different land use change rules were developed: one for high potential areas and one for dryland areas.

For the high potential areas, the rules to convert convertible land into arable land are based on an equal weight of normalized distance to existing cropland (computed from the study site specific land cover map) and normalized suitability of cropland that is based on the GAEZ layer suitability for low input rainfed cereal production. In simple words, this procedure will convert the most suitable plot for crops near to existing cropland first and least suitable plots far away from existing cropland last. In between there is a trade-off between suitability and distance to existing crop. This approach reproduces the observed land use change pattern, where cropping encroaches on other land uses next to the already existing cropland.

For the dryland areas, even high resolution land cover maps at 30 sq. m do not capture the single small cropped fields within the savannah in drylands. These are often rotating every year, i.e. the cropped fields are found in a different place, yet their total number is increasing. This is why the land use change model for drylands is a random conversion of the convertible savannah into arable land, where the user fixes the additional number of cropped fields needed. In the particular case of Burkina Faso, convertible savannah was defined as savannah that is not located within the agreed livestock routes (GRAF, 2014).

Deciding which Land Use Change rules or options apply in each study area is the responsibility of the modeller, based on expert knowledge of possibility of land use change, and the potential and likely type of land use change in the study area. Specific land use change rules for the three existing tools can be found in the CLEANED R Documentation for each tool (Pfeifer et al., 2018b, 2018c, 2018a).

2.3.3 Water module

The water module computes the quantity of water needed to grow the total biomass demanded by the herd to meet their energy requirement for a year (an output from the Production and Land Allocation module). It takes into account that different feed and fodder types require different amounts of water to grow. This is based on annual evapotranspiration for the portion of the crop biomass that is fed to livestock (see Table 1). The total water required for feed production is then distributed over the crop and grazing land pixels, according to how much feed is demanded from each land category (another output from the Production and Land Allocation module). For each pixel across the study area, the amount of water required for feed production for a year is then compared with the total amount of rainfall received in that pixel over a year based on the mean annual rainfall for that pixel. This provides a measure of the water impact, per pixel, as the ratio of water needed over actual rainfall in the area as follows :

$$\frac{\sum_f^F \quad ET_f}{annual\ rainfall}$$

Where ET_f is evapotranspiration for a specific feed (f) in the total feed basket (F)

The map resulting from the above-mentioned equation shows where water stress is likely, as well as the change in this indicator compared to the base run. In addition to the map, the CLEANED R output tables present other metrics for the whole area such as total water usage, and water usage per animal, per ton of milk, and per ton of meat. All metrics are presented both in terms of absolute values and relative change (%) compared to the base run.

The water module therefore does not include water used by livestock on the farm, for example for drinking or washing or administering medicine (e.g. spraying for ticks), or any of the water used 'beyond the farm gate' in meat and milk processing, for example. This is because the water consumed by the animal directly is only a small percentage compared to the total amount of water needed to grow the biomass for the livestock feed (Descheemaeker et al., 2010).

2.3.4 Greenhouse gas module

The greenhouse gas impact was computed using IPCC tier 2 computations (IPCC, 2006) for total greenhouse gas emissions from livestock production considering emissions from:

1. Enteric fermentation, which was considered to be uniformly distributed throughout the whole study area.
2. Manure management, including methane emission and nitrous oxide emissions; the latter includes the direct emissions from manure as well as the indirect emissions that occur when manure is stored. Greenhouse gas emissions from manure were allocated to cropland and grazing land based on a land cover map. Manure emissions from grazing animals is allocated to the point of emission, namely the grazing land. The emissions from manure of animals at the farmstead were artificially allocated to cropland, assuming that the animals are kept in the farms surrounded by those fields.
3. Feed and fodder production (from land management and land use change) which was allocated to grazing land, to cropland and to land converted to cropland based on a land use change map.

The maps show the total greenhouse gas emissions (in $C0_2$ equivalent), from manure management only, as well as the change in these indicators compared to the base run. CLEANED R also produces output tables with other metrics including the greenhouse gas emissions for all animals of a type (e.g. cattle, or sheep), greenhouse gas emissions per animal as well as per product both in terms of absolute values and relative change (%) compared to the base run. As GHG are volatile and not bound to location, it makes sense to focus on the results in the tables rather than on the map, that allocate GHG to point of emissions.

Emissions associated with livestock 'beyond the farm-gate' are not included, for example meat and milk processing or transport to market and consumers. At this stage, fuel for tractors that might replace draught oxen is also not included.

2.3.5 Biodiversity module

The biodiversity measures are based on the IUCN red list (IUCN, 2017). A species richness index is computed to show where most endangered species are located: this is, for each pixel, the ratio between the number of species making use of the given pixel and the total amount of endangered and critically endangered species. The number of species making use of a given pixel is based on land use as an indication of habitat.

In the case of a land use change, it also computes for each pixel that is changed how many species that are critically endangered use that pixel as critical habitat, and will therefore lose a piece of their critical habitat which can threaten the survival of this species. For example, some migratory birds are critically endangered because their nesting habitat in Europe is disappearing. Their habitat in Africa is not critical for survival and is not considered as critical habitat within CLEANED R, and would not count in this latter measure of biodiversity.

The map shows the variation in the calculated species richness index across the study area, and the number of species losing critical habitat in the event of land use change. Note that unless land use change is incurred/implemented in a scenario, the biodiversity indicator will not change, as the species richness index is tied to land use, rather than the type and management of animals in the scenario.

Output tables show the average species richness index for the study area and the average number of species losing critical habitat across the study area (in the event of land use change).

2.3.6 Soil health module

The nitrogen balance is a proxy for soil health and is computed as the difference between the amount of nitrogen added to the soil and the amount extracted (Smaling et al., 1993). The nitrogen added consists of manure and chemical fertilizer that is added to the soil, atmospheric deposition, and biological fixation. The extracted nitrogen consists of nitrogen absorbed by the plants that constitute the feed and fodder, erosion, nitrogen leaching, and gaseous losses (Table 2).

Table 2: Components of the nitrogen balance (after Smaling et al 1993)

Nitrogen added to the soil	Nitrogen extracted from soil
Mineral fertilizer (Ni)	Biomass yield (crop yield + crop residue, Nyield+Nres)
Organic fertilizer (M)	Leaching (L)
Atmospheric deposition (A)	Gaseous losses (G)
Biological fixation (B)	Erosion (E)
Nitrogen Balance	

The computations for the nitrogen balance follow the equations presented in Smaling et al (1993) with the exception of erosion. CLEANED R computes erosion based on a spatially explicit RUSLE model, following the procedure presented in Claessens (2008) that was developed for East Africa. It was possible to apply this procedure across the whole of Africa by replacing any set parameters proposed in Claessens (2008) that reflected conditions specific to East Africa with equations computing those parameters for any location in Africa, as proposed in Panagos (2015). The layers created based on these equations made use of a series of soil characteristics from soilgrids data (Hengl et al., 2015), as well as using new rainfall erosivity data derived from satellite images (Vrieling et al., 2010).

The CLEANED R output maps show the nitrogen balance, the nitrogen added to the soil (tons), and the nitrogen extracted from the soil (tons), as well as the change in these indicators compared to the base run. The output tables provide metrics for nitrogen balance (unitless), total nitrogen added (tons), total nitrogen extracted for the study area (tons) and total amount of manure produced (tons) both in terms of absolute values and relative change (%) compared to the base run.

2.4 Output

Each time the user runs CLEANED R, the tool calculates the metrics mentioned in the preceding chapter for each module and displays them in map and table formats. In both formats, the tool also calculates the percentage change in these metrics compared to the base run (Box 2).

Box 2: Scenarios and the base run

A scenario refers to one possible mix of different livestock production practices in a defined landscape, represented by the livestock categories in the tool. This encompasses the types of livestock production practices assumed to be present and the proportion (or scale) of each practice. For a particular scenario, CLEANED R calculates the environmental impact from the mix of livestock production practices in a landscape.

The base run represents the current situation at the time of developing the model, to the best knowledge and practicality of the modeller. That is, a 'scenario' where the input variables are set to the current number of livestock in each category as per available statistics, or as best as the modeller is able to calculate them from other data sources. The animals also have live weight, meat and milk production and feed basket as similar as average conditions for each category that also, when running tool with these settings, produces a biomass use that looks familiar, considering what the modeller and experts know of use of biomass and other resources in the area.

2.4.1 Interfaces

The CLEANED R tool is coded in R and requires quite some experience with coding language to be run correctly. This is why an R Shiny interface was developed that allows a non-coder to use the tool in an intuitive way. The R Shiny interfaces are developed for online deployment on the shiny.io platform, making the tool accessible from anywhere in the world. However, often workshops take place in areas with limited internet connectivity, and for this reason, the codes for each of the existing study site tools have been released on GitHub allowing a standalone installation of the tool on a laptop. The last chapter of this document goes into the detail for the installation of the standalone tool, as well as a link to the GitHub and links to each of the existing tools.

The R Shiny interface for each study site includes three pages[9]:

i) a welcome page with information about the study site and treatment of parameters specific to that study site (study boundary, livestock categories, pre-set options)
ii) a page with a simplified version of the tool that has pre-set options to choose from when building scenarios (see section 2.4.2 for more detail)
iii) a page with an expert version of the tool that allows users to manually define every single user-defined variable used in defining a scenario

Each tool interface page has five tabs: the *Production* tab, and a tab for each of the four environmental modules (*Water impact, Greenhouse gas impact, Biodiversity impact and Soil impact*).

The *Production* tab is where the user enters the variables that will define the scenario and begins running the tool by running the Production and Allocation module and calculating the feed basket and associated land use for the scenario. In the simplified version, the user enters the number of animals to be in each category, and then selects a management option for each category (these are the pre-set options, see section 2.4 2). In the expert version, the user enters the number of animals to be in each category, and then has the ability to change any of the variables to tailor the management options to their desire. The numbers that are already set by default represent the variables that describe the base run 'scenario'. If the user runs the tool without changing any of the variables, the results produced will be the base run, and the difference to the base run will be 0% for all results (for example, see Figure 3, right side).

The tabs for each environmental module (*Water, Greenhouse gases, Biodiversity and Soil*) contain a button to run that module for the scenario (implying that the user can choose to only run selected environmental modules) and the maps and output tables that appear after running the module.

2.4.2 Pre-set options for creating scenarios

The CLEANED R tool has a large number of parameters that are user defined, namely around livestock characteristics and management. For experts who study livestock systems, these variables are relatively easy to define, however it might be a challenge for other actors, such as policymakers. It is very tempting to define a "super cow", an unrealistic animal that produces a high amount of animal sourced food (meat and milk production) without defining enough resources to sustain that production. To avoid unrealistic user-defined parameters, a simplified version has been developed that uses pre-set options for creating scenarios, to complement the expert version of CLEANED R.

Pre-sets are combinations of animal characteristics and management in each category that are credible, namely an animal weight and a feed intake that can truly lead to the defined productivity of animal sourced food. A selection of pre-sets for each category can be created for each category that describe alternative ways or pathways in which the management of animals in that category might change in the future. The user can then pick and choose their own compilation of pre-sets across the categories (one pre-set per category) to describe their strategy for managing the transition to the future, which defines their scenario.

For each existing study site tool, animal feed experts who have knowledge or experience of locally available animal breeds collaborated to develop these pre-sets. Figure 2 shows an example of the pre-set options from Ethiopia. In this case, the first option is the base run management, with two options for alternative strategies

[9] The interface for Bama, Burkina Faso, also includes tool pages for the simplified and expert versions of the tool in French.

for reaching the same improvement in meat and milk yield. In other countries, the two non-base run options offered two steps of incremental improvement in meat and milk yield. These pre-sets can be defined to describe any set of options that the user would like to be able to explore, and in theory any number of pre-set options per category could be defined. The pre-set options are defined in an excel file and can be easily adjusted.

	Code	Description
Dual purpose dairy cattle (DD) – local breed	DD0 : baseline (current state)	The current way to keep lactating dual purpose animals, mainly fed on natural grass, crop residue and very slight amount of concentrates*.
	DD1 : improved farm produced feed basket	Improved feed basket for lactating dual purpose animal, with more concentrates, natural grass is mainly replaced by planted fodder.
	DD2 : improved commercial feed basket	Improved feed basket for lactating dual purpose animal, with more concentrates than DD1, natural grass and hay.
Dual purpose fattening and rearing cattle (DF) – local breed	DF0 :baseline (current state)	The current way to keep non- lactating dual purpose animals, mainly fed on natural grass, crop residue and very slight amount of concentrates.
	DF1 : improved farm produced feed basket	Improved feed basket for non- lactating dual purpose animals, with more concentrates, natural grass is mainly replaced by planted fodder.
	DF2 : improved commercial feed basket	Improved feed basket for non- lactating dual purpose animals, with more concentrates than DF1, natural grass and hay.
Draft animal (DA) – local breed	DA0 : baseline (current state)	The current way to keep draft animals, mainly fed on natural grass, crop residue and very slight amount of concentrates.
	DA1 : improved feed basket	Improved feed basket for draft animals, with more concentrates, but still mainly fed on natural grass.
Improved dairy cattle (SD) – cross breed	SD0 :baseline (current state)	The current way to keep cross-breed animals, already having a good proportion of concentrates.
	SD1 : improved feed basket	Improved feed basket for cross-breed animals, with slightly more concentrates but partly replacing natural grass and crop residues with planted fodder.
	SD2 : fully commercial feed basket	Improved feed basket for cross-breed animals, with only concentrates and planted fodder, no natural grass, no crop residue.
Sheep rearing and fattening (SH)	SH0 : baseline (current state)	The current way to keep sheep, mainly fed on natural grass, crop residue and very slight amount of concentrates.
	SH1 : improved farm produced feed basket	Improved feed basket for sheep, with more concentrates, and natural grass is partially replaced by planted fodder.
	SH2: improved commercial feed basket	Improved feed basket for sheep, with more concentrates than SH1, natural grass and hay.

* Concentrates include bran mixes, local brewery residue (*atella*) and oilseed cakes such as noug, sesame and cotton cakes.
* Crop residues include wheat and barley straw.

Figure 2: Pre-set options for the CLEANED R tool for Atsbi, Ethiopia.

2.4.3 Reading the outputs

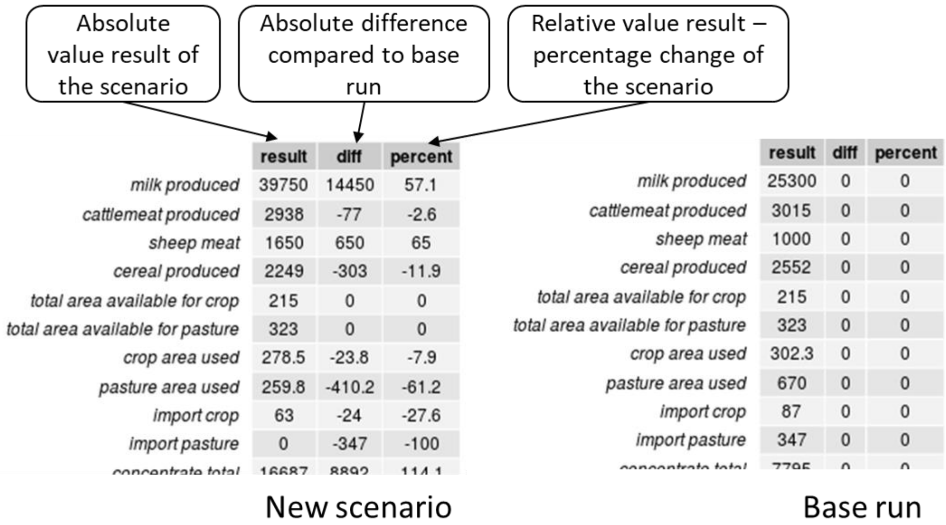
The results are presented in absolute values, and in relative values that present the % change compared to the base run. The results are presented in a map format that shows the results per pixel and therefore shows variation in the results across the study area, based on land use and other geographical variables. Summary results for the study area are also provided in table format (Figure 3)[10]. The first column titled 'result' gives the absolute values resulting from the scenario_that is being run[11]. The second column titled 'diff' gives the absolute difference between the scenario results (column 1) and the base run and the third column calculates the relative percentage that the 'diff' column represents.

While the absolute values are presented for transparency and trouble-shooting, the important and more reliable values to use when reading the outputs are **the relative percentage change values** in column three[12].

As mentioned in Box 1, given the uncertainty in the modules due to the complex nature of livestock systems that we are representing with simple equations, as well as any uncertainty in the input data, the absolute values cannot be assumed to be accurate. However, for a scenario describing some change to the livestock

[10] In our experience of using the tool in a multi-stakeholder workshop setting, the tables are more easily interpreted in a group setting where time is short, and therefore more useful.
[11] In the Burkina Faso tool, this column is erroneously titled 'base'. Revisions to the format of presenting the results will be made in due course, including changing the headings of the output table columns to be more intuitive. Feedback on further alterations is welcome.
[12] Note that in the Burkina Faso tool, in the production tab the relative change is shown as a ratio (e.g. 0.7) as opposed to a percentage (e.g. 70%). The rest are shown as percentages.

herd, the relative change values give a good idea of the direction and magnitude of potential change compared to the present situation.



New scenario

	result	diff	percent
milk produced	39750	14450	57.1
cattlemeat produced	2938	-77	-2.6
sheep meat	1650	650	65
cereal produced	2249	-303	-11.9
total area available for crop	215	0	0
total area available for pasture	323	0	0
crop area used	278.5	-23.8	-7.9
pasture area used	259.8	-410.2	-61.2
import crop	63	-24	-27.6
import pasture	0	-347	-100
concentrate total	16687	8892	114.1

Base run

	result	diff	percent
milk produced	25300	0	0
cattlemeat produced	3015	0	0
sheep meat	1000	0	0
cereal produced	2552	0	0
total area available for crop	215	0	0
total area available for pasture	323	0	0
crop area used	302.3	0	0
pasture area used	670	0	0
import crop	87	0	0
import pasture	347	0	0
concentrate total	7795	0	0

Figure 3: Output of the CLEANED R tool in table format - absolute and relative values

These potential changes should be interpreted in reference to local knowledge of how current biomass and natural resource use impacts livelihoods and the environment. For example, if water is already constrained and presents a challenge for users, then any increase in water use might be considered concerning, as some measures to make more water available will need to be made. It is for this reference to local knowledge that we suggest that the CLEANED R tool is used within a multi-stakeholder participatory process such as the Transformation Game (Morris et al., 2019), to collect diverse local knowledge with which to interpret the outputs.

2.4.3.1 *Common dynamics*

While the tool is built to deal with non-linearities in the system that we could not calculate ourselves, and therefore the specificities of each study site will dictate the dynamics that explain the results, there are some common points to bear in mind that might help explain the results. Note that these are not yet based on a systematic testing of the tool, but based on expert knowledge gathered in the modelling process.

- Planted fodder is more water intensive than crop residues
- Heavier animals imply more greenhouse gases – yet when fed correctly, their productivity might be much higher and therefore greenhouse gas emissions per product, i.e. per kg of meat or per litre of milk, is lower than the emissions per product from lighter animals.
- Improved feeding implies feed with a higher crude protein content, based on IPCC tier 2 computations, and this suggests that the animals have a higher nitrogen consumption. CLEANED R does not have a herd model, and assumes milk fat content is constant leading to a constant nitrogen retention. Given these assumptions, an improved feed basket always leads to more GHG emissions.
- Shifting from natural grass to planted fodder implies, in this model, a shift from using grazing land to using cropland. Therefore, users should consider the change in cropland required against knowledge of current cropland availability. If all cropland is currently in use, what will be sacrificed to make cropland available for planted fodder? How will that extra cropland be made available? In the tool, we have made a simple measure that shows, assuming the majority of crop land would be planted with cereals (maize or wheat etc.), how much cereal production would be lost by the planned increase in planted fodder. This measure is meant to catalyse a critical discussion of what changes in cropland use would actually be required to support the planted fodder. Planted fodder also typically requires lots of rain or irrigation.
- The way biodiversity has been implemented, it is only relevant when a land use change is implemented.

3 Setting up a CLEANED R tool for a new area

CLEANED R aims to provide a simple tool that can be quickly set up, is not data-intense and yet can reflect the variation and specificities of a given site, making it locally relevant. In conjunction with the transformation game, it can bring people with completely different stakes together to explore the complexity of the livestock sector, as well as potential conflicts, and find constructive solutions. This however comes at the cost that CLEANED R is not a 'plug-and-play' tool that can be directly used in another location other than the three study areas for which tools have already been set up. This is in spite of having an automatized procedure to extract environmental parameters from geographical layers, such as soil characteristics or rainfall, which suggests that if you provide GIS layers for a new location, the tool could be used for that new area. However, this assumes that everything else about the new area is exactly the same as in the initial study area, which will rarely be the case.

The CLEANED R tool uses three types of parameters to describe the study area: i) the livestock categories; ii) the geographical conditions extracted from GIS layers; and iii) the livestock management and other parameters not available in GIS layers (see section 3.1). The automatized procedure extracts parameters for the second type of parameters. If anything in the first or third type of parameters is different in a new area, then a new tool needs to be developed that is relevant to that area. If the difference is only in the third type of parameters, the changes are simpler. If the difference is in the first type of parameters, the livestock categories, the changes required to develop a new tool may be extensive.

It is therefore recommended to contact us if you are interested in using the CLEANED R tool in a new area, to assess how to set it up for your area (Catherine Pfeifer, catherine.pfeifer@fibl.org).

3.1 Assigning initial values to CLEANED R parameters

This section describes what is required for gathering or extracting the parameters in the three types of parameters in CLEANED R.

Firstly, the parameters to characterise *the livestock categories* are user defined: that is live weight of an average adult animal, animal sourced food production per year and the feed basket (split by wet and dry season if there is significant difference between the two). For the SAIRLA tools, these numbers were fixed for two to three pre-set options within each livestock category, based on animal feed and breed experts as well as locally relevant literature. The livestock categories themselves (e.g. draft animals or sheep or specialised dairy) were chosen based on consultations and literature review about the most common types of livestock keeping in the study area. The means of classifying livestock into categories differ, with implications on how the livestock categories are described and used. Some classify by livestock products (meat, milk etc.), some by livestock function (dairy, draft, fattening etc.), some by management practices (e.g. extensive low input, intensive high input and other variations). In essence for coding CLEANED R, the distinction between livestock categories is in how different the feed basket, animal and manure management, and animal characteristics are.

Secondly, there is a whole set of parameters that can be extracted from *geographical layers*, namely from those layers described in Table 1. This extraction is very intensive but can be performed automatically by R using standard procedures[13]. This procedure is fully automatized but can take up to 72 hours processing time, depending on the size of the study area and the strength of the computer.

Lastly, there is a set of parameters for which no geographical layers exist and therefore are *semi-manually defined*. Most of these parameters are manually entered into an excel sheet that is called upon in CLEANED R by some modules. These parameters mostly include feed and fodder characteristics (crude protein content, proportion of biomass that is crop residue) and are extracted from the Feedipedia database manually

[13] The extraction codes used in the ResLeSS project are available on request.

(https://www.feedipedia.org/), or parameters from the IUCN red list of endangered species which are extracted manually for each study area for the biodiversity pathway.

To set up the CLEANED R tool, an initial number of animals in each livestock category needs to be defined. These numbers can be deduced from a triangulation exercise that compares data from experts, national statistics, results from workshop 1 and where available Demographic Health Surveys (MEASURE DHS/ICF International, 2013).

When all parameters have a locally relevant value assigned to each parameter and initial livestock numbers are defined, the draft version of the CLEANED R tool is ready. With this version a base run needs to be defined, i.e. one needs to adjust parameters and initial numbers of livestock so that the base run reflects the current situation as much as possible. This is quite tedious work if not almost an art, where numbers of livestock and parameters are manually adjusted within a credible range to reflect the locally observed dynamics. This assumes that the modeller has a good understanding of the study area, both in terms of the biophysical characteristics and of the issues driving discussion in the area to make the CLEANED R tool useful to give answers to the major open issues and conflicts in the study area. For example, the Ethiopian study area regularly requires food aid as a slight climatic change from the average rainfall leads to major loss of the harvest. As CLEANED R is based on an average year, it is not credible to assume that this area has a biomass surplus allowing to feed double the current number of animals without importing feed and forages.

Once all parameters have been defined to produce a credible base run, all outputs from this run need to saved and pasted into the base run folder, which is used by the tool when computing the difference from the base run for a new scenario being run.

3.2 Towards a full modularization of CLEANED R

As explained above, the CLEANED R tool is not a 'plug-and-play' tool that can be picked from the shelf and run for a different area for two reasons: firstly, because livestock categories and land cover are different in each tool, and secondly because fine-tuning the base run to reflect the current situation requires quite some local knowledge. However, in the long term, further developments could be made to the tool to allow a new tool to be set up for a new area more easily.

First, it is imaginable that CLEANED R is recoded in such a manner that there are separate pre-coded modules[14] available that represent the most commonly found livestock categories such as pastoral dairy, pastoral transhumant animals, improved dairy cattle (cross breeds), pure breed dairy cattle, dual purpose lactating cows[15], dual purpose fattening, draft animals, goats and sheep. The person creating a new tool could then request which livestock categories to include in the tool to represent their study area.

Secondly, if the tool would be coded for one of the new high resolution land cover products, the CLEANED R tool could be set up for a new area much more quickly than today. However, this would require a full recoding of the CLEANED R tool with the modular structure described above and it would still not be plug and play because the definition of the base run needs to be done by a modeller who understands the study area and the environment well.

[14] Ensuring that the energy calculations are appropriate to the animal being represented in that category, among other things.

[15] Dual purpose refers to the animal being kept for more than one purpose, not specifically for milk or meat alone, which means the rationale for how the cow is kept is very different to animals kept for a single purpose of producing milk or meat.

4 Existing tools to date

The CLEANED R tool has been set up for three locations as part of the ResLeSS project funded by SAIRLA, for Bama in Burkina Faso, Atsbi in Ethiopia and Lushoto in Tanzania. For each area, three versions of the tool exist, namely a raw R version, a standalone R Shiny version (i.e. the raw R version with a user friendly interface) and an online Shiny version. For both standalone and online R Shiny version, there are two interfaces, namely the simplified version in which the user can select the pre-set options used in the Transformation Game, and an expert version in which the user can change all input variables manually.

All codes are found on GitHub under a Creative Commons licence which allows others to use the code in any way, as long as their work references the original code correctly: https://github.com/ilri/CLEANED-R. To find out more about licencing, visit https://www.gnu.org/licenses/gpl-3.0.en.html.

4.1 Online R-Shiny version

The online version can be found at the links listed in Table 3.

Table 3: List of links to the R Shiny interfaces for the study-site specific tools

Country	Interface	Link
Bama, Burkina Faso	Simplified	https://ilri.shinyapps.io/cleaned-r-resless-bama_bfa/
	Simplified French	https://ilri.shinyapps.io/cleaned-r-resless-bama_bfa_f2/
	Expert	https://ilri.shinyapps.io/cleaned-r-resless-bama_bfa_ex/
Atsbi, Ethiopia	Simplified	https://ilri.shinyapps.io/cleaned-r-resless-atsbi_eth/
	Expert	https://ilri.shinyapps.io/cleaned-r-resless-atsbi_eth_ex/
Lushoto, Tanzania	Simplified	https://ilri.shinyapps.io/cleaned-r-resless-lushoto-tza/
	Expert	https://ilri.shinyapps.io/cleaned-r-resless-lushoto_tza_ex/

4.2 Working with the standalone tools

Standalone tools are the interfaces that can be found online, but run on the computer locally. This requires that all the software and their related packages are installed. In addition, some basic skills in running R and R-studio are an advantage.

4.2.1 Requirement specifications

4.2.1.1 *Software requirement*

- CLEANED R tool (this can be downloaded from https://github.com/ilri/CLEANED-R)
- R statistical software (version 3.3.2 and above; this can be downloaded from https://cran.r-project.org/bin/windows/base/)
- Rstudio Desktop (this can be downloaded from https://www.rstudio.com/products/rstudio/download/)
- In principle, these software can be downloaded for Windows, Mac OS and Linux. This guide illustrates the installation on the Windows operating system.

4.2.1.2 *Hardware requirement*

- A minimum of 4GB RAM on the PC or laptop

- 64bit PC or laptop

4.2.1.3 *Other requirements*

Input data: The dataset of geographical layers and semi-manually defined parameters is specific to the area of interest, and therefore specific to each tool. It can be downloaded from the GitHub (link above), by finding the folder or link for the study area of interest on the GitHub, and then following a link to a Google Drive as directed in the Readme for each study site tool. The Google Drive contains three zipped folders all of which should be downloaded and stored temporarily.

4.2.2 Installation and running the standalone tool

In order to install and run the stand-alone tool as explained below, one is required to have basic skills in working with R and Rstudio.

4.2.2.1 *Installation*

1. Download and install R (https://www.r-project.org/) and Rstudio (https://www.rstudio.com/products/rstudio2/) for your operating system as per their installation manual.
2. Download the CLEANED R tool for the chosen study site into a new folder with the name CLEANED-R
3. Navigate to this CLEANED-R folder, documentation and open and run install_packages.r R code in Rstudio to install required packages (the required packages are: *sp, raster, maptools, RColorBrewer, rgdal, igraph, gridExtra, shiny, shinydashboard*, *shinyjs*,and *rgeos*). To do so press the button *run* in the top window left. This may take a few minutes depending on your internet connection. Alternatively, you can install the packages manually from the package window in R-shiny.
4. In your CLEANED-R folder, create two sub-folders in it named ***1-input*** and ***4-output***.
5. Unzip the downloaded input data using the same folder names as in the google drive into ***1-input*** folder. ***4-output*** remains empty for now but will contain the outputs from each run as pdf, as well as the outputs data as csv or geotiff format.

4.2.2.2 *Running the tool*

1. Inside the folder where you have created the two new sub-folders (***1-input*** and ***4-output***) and containing the CLEANED R tool of your interest, open *CLEANED_INTERFACE_WITH_PRESETS_*country*.r* or *Interface-preset.r* or *Interface-English.r* in Rstudio.
2. In the opened R shiny script in Rstudio, change the directory path shown by 1 in Figure 4 below to the path of the folder of CLEANED-R, i.e. look for line of code that reads "path <<- 'D:/Dropbox…." and put here the path to your folder. Note that on Windows you need to change the \ into / manually if you copy and paste the path to your folder from the windows explorer.
3. Click ***Run App*** shown by number 2 in Figure 4 below. A new pop up window will appear with the standalone R shiny version of the CLEANED R tool (see Figure 5).

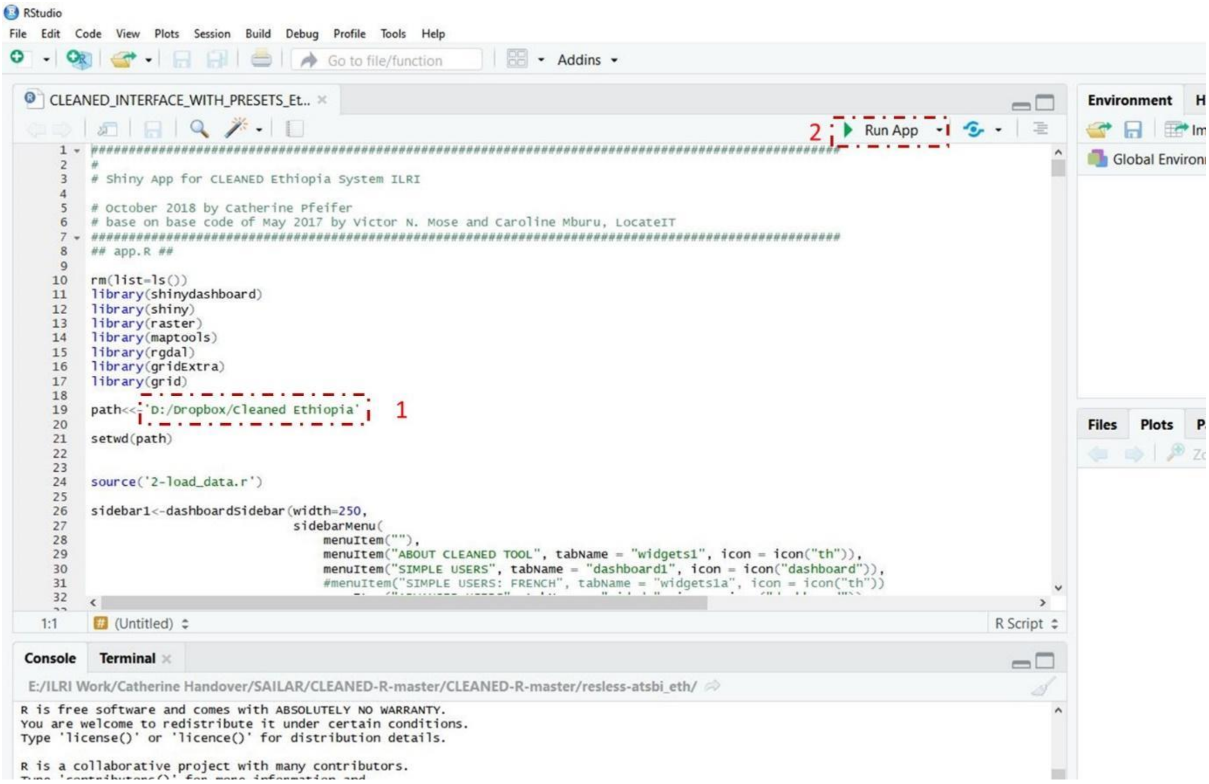


Figure 4: Changing the working directory in the R Shiny interface script of the standalone tool

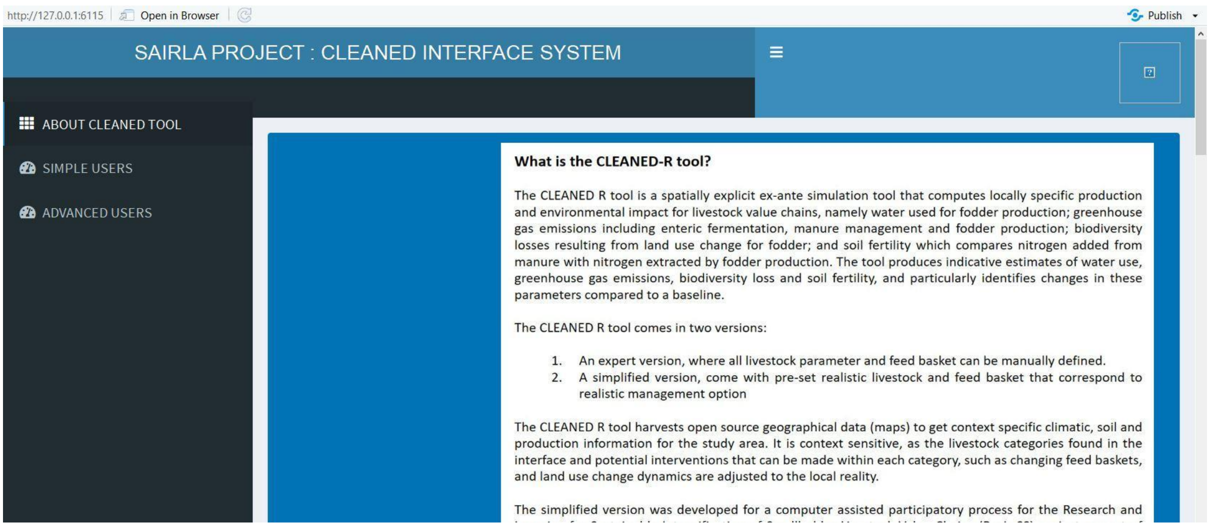


Figure 5: Standalone R Shiny interface for the CLEANED R tool

5 References

Claessens, L., Breugel, P. van, Notenbaert, A.M.O., Herrero, M.T., Steeg, J. van de, 2008. Mapping potential soil erosion in East Africa using the Universal Soil Loss Equation and secondary data, in: Sediment Dynamics in Changing Environments. Presented at the Proceedings of a symposium held in Christchurch, New Zealand, International Association of Hydrological Sciences, Christchurch, New Zealand, pp. 398–407.

Descheemaeker, K., Amede, T., Haileslassie, A., 2010. Improving water productivity in mixed crop-livestock farming systems of sub-Saharan Africa. Agric. Water Manage. 97, 579–586. https://doi.org/10.1016/j.agwat.2009.11.012

Ensor, J., Pfeifer, C., Morris, J., Ouedraogo, S., 2018. Exploring alternatives for livestock production in Bama, Burkina Faso: Playing the Transformation Game. Report of ResLeSS Workshop 2 (SAIRLA Project report). Stockholm Environment Institute, York.

Fischer, G., Nachtergaele, F.O., Prieler, S., Teixeira, E., Toth, G., van Velthuizen, H., Verelst, L., Wiberg, D., 2012. Global Agro-ecological Zones (GAEZ v3.0)- Model Documentation. IIASA, Laxenburg, Austria and Rome, Italy.

GRAF, 2014. Pastoralisme : Pistes salvatrices (GRAF Infos No. 35). GRAF.

Hengl, T., Heuvelink, G.B.M., Kempen, B., Leenaars, J.G.B., Walsh, M.G., Shepherd, K.D., Sila, A., MacMillan, R.A., Jesus, J.M. de, Tamene, L., Tondoh, J.E., 2015. Mapping Soil Properties of Africa at 250 m Resolution: Random Forests Significantly Improve Current Predictions. PLOS ONE 10, e0125814. https://doi.org/10.1371/journal.pone.0125814

Hijmans, R.J., Cameron, S.E., Parra, J.L., Jones, P.G., Jarvis, A., 2005. Very high resolution interpolated climate surfaces for global land areas. International Journal of Climatology 25, 1965–1978. https://doi.org/10.1002/joc.1276

IPCC, 2006. Chapter 10 : Emissions from livestock and manure management, in: 2006 IPCC Guidelines for National Greenhouse Gas Inventories. Intergovernmental Panel on Climate Change.

IUCN, 2017. The IUCN Red List of Threatened Species. Version 2017-3.

Jarvis, A., Guevara, E., Reuter, H.I., Nelson, A.D., 2008. Hole-filled SRTM for the globe : version 4 : data grid. CGIAR Consortium for Spatial Information.

Kaplinsky, R., Morris, M., 2000. A Handbook for Value Chain Research. International Development Research Centre, IDRC, Ottawa.

MEASURE DHS/ICF International, 2013. Demographic and Health Surveys Standard Recode Manual for DHS6. (DHS toolkit No. No. DHSG4). The Demographic and Health Surveys Program, ICF, Rockville, Maryland, USA.

Morris, J., Ensor, J.E., Topi, C., Pfeifer, C., 2019. Facilitating the ResLeSS process: A learning process for inclusive, context specific planning in the livestock sector. Stockholm Environment Institute, York.

Myneni, R., Knyazikhin, Y., Park, T., 2015. MOD15A2H MODIS/Terra Leaf Area Index/FPAR 8-Day L4 Global 500m SIN Grid V006 [Dataset]. NASA EOSDIS Land Processes DAAC. https://doi.org/10.5067/MODIS/MOD15A2H.006

Notenbaert, A., Lannerstad, M., Barron, J., Paul, B.K., Ran, Y., Morris, J., Fraval, S., Mugatha, S., Herrero, M., 2016. Using the CLEANED approach to assess the environmental impacts of livestock production (CGIAR Research Program on Livestock and Fish Brief No. 17). International Livestock Research Institute, ILRI, Nairobi, Kenya.

Notenbaert, A., Lannerstad, M., Herrero, M., Fraval, S., Ran, Y., Paul, B.K., Mugatha, S., Barron, J., Morris, J., 2014. A framework for environmental ex-ante impact assessment of livestock value chains. Presented at the 6th All Africa Conference of Animal Agriculture, International Center for Tropical Agriculture (CIAT), Nairobi, Kenya.

Notenbaert, A.M.O., Paul, B.K., Mukiri, J., Birnholz, C., Koge, J., 2018. CLEANED X - Version 1.0.1: An user friendly Microsoft Excel tool to assess the environmental impacts of livestock production. Harvard Dataverse. http://dx.doi.org/10.7910/DVN/QIUJM5

Panagos, P., Borrelli, P., Poesen, J., Ballabio, C., Lugato, E., Meusburger, K., Montanarella, L., Alewell, C., 2015. The new assessment of soil loss by water erosion in Europe. Environmental Science & Policy 54, 438–447. https://doi.org/10.1016/j.envsci.2015.08.012

Pfeifer, C., 2019. CLEANED R - an ex-ante, landscape level environmental impact assement tool assessing changes from transforming livestock value chains. Stockholm Environment Institute and International Livestock Research Institute, Nairobi, Kenya.

Pfeifer, C., Morris, J., Lannerstad, M., 2016. The CLEANED R simulation tool to assess the environmental impacts of livestock production (CGIAR Research Program on Livestock and Fish Brief No. 18). International Livestock Research Institute, ILRI, Nairobi, Kenya.

Pfeifer, C., Morris, J., Mulatu, D.W., Wakeyo, M., Hruy, G., Ensor, J., 2018a. CLEANED-R Documentation: Conceptual overview of CLEANED and parameterisation of a CLEANED-R tool for Atsbi, Ethiopia. (SAIRLA Project report). Stockholm Environment Institute, York.

Pfeifer, C., Morris, J., Ouedraogo, S., Ensor, J., 2018b. CLEANED Documentation: Conceptual overview of CLEANED and parameterisation of a CLEANED tool for Bama, Burkina Faso (SAIRLA Project report). Stockholm Environment Institute, York.

Pfeifer, C., Morris, J., Soka, G., Moses, E.A., Ensor, J., 2018c. CLEANED-R Documentation: Conceptual overview of CLEANED and parameterisation of a CLEANED-R tool for Lushoto, Tanzania (SAIRLA Project report). Stockholm Environment Institute, York.

Pfeifer, C., Morris, J., Soka, G., Moses, E.A., Mkiramweni, N.P., Omari, A., Msoka, E., Kahamba, J.S., Sengelela, M.L., Mdoembazi, H., Massawe, B.H.J., Mahimbo, O., 2018d. Exploring alternatives for livestock production in Lushoto, Tanzania: Playing the Transformation Game. Report of ResLeSS Workshop 2 (SAIRLA Project report). Stockholm Environment Institute, York.

Pfeifer, C., Mulatu, D.W., Wakeyo, M., Arbissie, B., Berhe, M., Habtu Ferede, K., Hruy, G., Kidane, T., Mengistu, D., Mezgebe, K., Tadesse, T., Alemayehu, M., Gebremedhin, Z., Morris, J., 2018e. Exploring alternatives for livestock production in Atsbi, Ethiopia: Playing the Transformation Game. Report of ResLeSS Workshop 2 (SAIRLA Project report). Stockholm Environment Institute, York.

R Core Team, 2017. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria.

Rota, A., Sperandini, S., 2010. Value chains, linking producers to the markets (Livestock Thematic Papers), Tools for Project Design. IFAD, Rome, Italy.

Smaling, E.M.A., Stoorvogel, J.J., Windmeijer, P.N., 1993. Calculating soil nutrient balances in Africa at different scales. Fertilizer Research 35, 237–250. https://doi.org/10.1007/BF00750642

Vrieling, A., Sterk, G., de Jong, S.M., 2010. Satellite-based estimation of rainfall erosivity for Africa. Journal of Hydrology 395, 235–241. https://doi.org/10.1016/j.jhydrol.2010.10.035