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Sustainable Agricultural Intensification Research and Learning in Africa

CLEANED Documentation

Conceptual overview of CLEANED and parameterisation of a CLEANED tool for Lushoto, Tanzania

September 2018

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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 Ethiopian Development Research Institute (EDRI), 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 UK Department of International Development, 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.

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Acroymns

Acronym	
AFSIS	Africa Soil Information Service
C1	Cross breed somewhat improved
C2	Cross breed much improved
CBR	Cross breed baseline
CC	Climate Change
CIAT	International Center for Tropical Agriculture
CLEANED	Comprehensive Livestock Environmental Assessment for improved Nutrition, a secured Environment and sustainable Development
CO2	Carbon dioxide
CRP	CGIAR Research Program
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DFID	UK Department for International Development
DHS	Demographic Health Survey
E1	(mostly) Exotic breed somewhat improved
E2	(mostly) Exotic breed much improved
EBR	(mostly) Exotic breed baseline
ECRC/EDRI	Environment and Climate Research Center (ECRC) at Ethiopian Development Research Institute (EDRI)
FAO	UN Food and Agriculture Organisation
FEAST	Feed Assessment Tool
GAEZ	Global Agro-ecological Zones
GHG	Greenhouse Gas
GIS	Geographic Information System
ha	hectares
ICARDA	International Center for Agricultural Research in the Dry Areas
ILRI	International Livestock Research Institute
IMPACT	International Model for Policy Analysis of Agricultural Commodities and Trade
INERA	Institut de l'Environnement et de la Recherche Agricole
IPCC	Intergovernmental Panel on Climate Change
IUCN	International Union for Conservation of Nature
l	litre
L1	Local breed somewhat improved
L2	Local breed much improved
LBR	Local breed baseline
N	Nitrogen
NRI	Natural Resources Institute

OSS	Sahara and Sahel Observatory
ResLeSS	Research and Learning for Sustainable Intensification of Smallholder Livestock Value Chains
SAI	Sustainable Agricultural Intensification
SAIRLA	Sustainable Agricultural Intensification Research and Learning in Africa
SEI	Stockholm Environment Institute
SERVIR	Sistema Regional de VIisualización y Monitoreo de MesoAmerica
SUA	Sokoine University of Agriculture

Executive Summary

This companion document provides supporting information about the "Comprehensive Livestock Environmental Assessment for improved Nutrition, a secured Environment and sustainable Development along livestock value chains" (CLEANED) tool and how it has been parameterised for use in Tanzania, including a description of the study area. CLEANED is a spatial multi-dimensional and rapid environmental impact assessment framework of livestock value chains. It was developed to identify potential positive and negative environmental impacts of proposed practices or development interventions, and addresses the current gap in environmental assessment methods by being a rapid, multi-dimensional assessment tool including various spatial and temporal scales. For the "Research and Learning for Sustainable Intensification of Smallholder Livestock Value Chains" (ResLeSS) project, CLEANED has been applied in Burkina Faso, Ethiopia and Tanzania.

The CLEANED model focuses on environmental impact of livestock value chains associated with feed production, which constitutes the major source of environmental impacts related to livestock value chains. Environmental impact is categorized into four key impact dimensions that are used as proxies to assess environmental change. Three dimensions, I) water, II) land/soil and III) biodiversity, are impacting the local environment, while the fourth, IV) greenhouse gas (GHG) emissions, is used to assess the contribution to global climate change (CC). The tool uses pixel based modelling with spatial input data to generate output maps showing the distribution of environmental change in relation to baseline conditions. As such the CLEANED tool can be seen as a way to give meaning to the many openly available but difficult to interpret GIS data for the context of transforming livestock value chains.

In Tanzania, the focus is small scale dairy production in the district of Lushoto, Tanga Region, Tanzania. Lushoto is located is in the mountains near to the Kenyan boarder. The reconnaissance work has shown that smallholders keep cattle for dairy in three different systems: extensive in the lowland, semi-intensive and intensive in the highlands. Yet, discussion about future developments in the first ResLess workshop have pointed out that in all three systems smallholders are trying to improve the breeds. This is why the CLEANED Tanzania works with breeds, namely preliminary local breeds, cross breeds (with 65-85% exotic genes), almost pure breed (more than 85% exotic breed). Local breeds are mainly found in the lowlands and are mainly fed on natural grasses and some crop residue. The cross-breeds are found in the highlands and are mainly fed on a mix of natural grass, crop residues and a bit of concentrate. In this system the main issue is the feed shortage in the dry season, which can be addressed with the production of hay and silage. Also planted feed, which has higher nutritional value than crop residues could be used to improve milk productivity per cow. The almost pure breed is a category is only marginally existent in Lushoto in the current situation. These animals needs much more care and hardly feed on natural grasses and crop residues, but mainly on planted fodder and concentrates.

Initial livestock population numbers to parameterise the 'base run' in CLEANED (a scenario that represent the present day situation) are calculated for the three categories using a triangulation between the participatory GIS activities in the first workshop, freely accessible spatial data layers and household survey and verified against provincial livestock population statistics from FAO and data available from the district office and Demographic Health Surveys (DHS).

To make it easy and fast for users to build scenarios of livestock production in Lushoto (how to produce in each category and how many animals per category) in a workshop setting, a set of 'vignettes' was produced that describe credible combinations of feed baskets with animal productivity for each animal category representing two or three different livestock management options within each production category. These vignettes are pre-set within the CLEANED tool code, so that the non-expert can develop credible scenarios.

This document accompanies the report of the second ResLeSS workshop in Lushoto, Tanzania, titled "Exploring alternatives for livestock production in Lushoto, Tanzania: Playing the Transformation Game", which presents the design and results of the workshop.

1 Introduction

This report is a companion document to the Transformation Game Workshop report for Tanzania, which describes the design and outputs of the second workshop in Lushoto District, Tanga Region, Tanzania, for the Research and Learning for Sustainable Intensification of Smallholder Livestock Value Chains (ResLeSS) project, which is part of the Sustainable Agricultural Intensification Research and Learning in Africa (SAIRLA) programme, funded by UK DfID and managed by the Natural Resources Institute (NRI) at the University of Greenwich and WYG. The two workshops and a preceding reconnaissance tour form the ResLeSS process, a participatory process designing according to social learning design principles that brings multiple stakeholders together to first consolidate in stakeholder groups their priorities for what a successful livestock future means and should deliver, and then to negotiate in mixed groups how to design scenarios for the future to fulfil all groups' priorities. The ResLeSS process combines using a rapid ex-ante environmental impact assessment tool (CLEANED[1]) and a participatory economics approach together with input from local stakeholders, to produce decisions that have taken into account three pillars of sustainability – the environment, economics and equity.

This companion document provides a conceptual overview of the "Comprehensive Livestock Environmental Assessment for improved Nutrition, a secured Environment and sustainable Development along livestock value chains" (CLEANED) tool (Chapter 2). CLEANED was originally developed during 2013-2015, in a collaboration between the Stockholm Environment Institute (SEI), the International Center for Tropical Agriculture (CIAT) and the Commonwealth Scientific and Industrial Research Organisation (CSIRO) and International Livestock Research Institute (ILRI), funded by Bill & Melinda Gates Foundation.

In the ResLeSS project, CLEANED has been applied in, Burkina Faso, Ethiopia and Tanzania. The conceptual idea of the ResLess project, the ResLeSS process, combines top-down modelling to bottom-up participatory methods in an iterative process of scenario design and evaluation in order to identify trade-offs between different socio-ecological impacts of sustainable intensification, and enhance adaptive capacities to handle these. This report provides details of how CLEANED has been applied and parameterised for use in Tanzania, including a description of the study area (Chapter 3).

CLEANED is implemented as an R code, with an RShiny user interface. Basic information about the main functions of the tool and a guide to using the interface are presented in Chapter 4.

2 Conceptual overview of CLEANED

2.1 The conceptual CLEANED tool

CLEANED is a spatial multi-dimensional and rapid environmental impact assessment framework of livestock value chains (Notenbaert et al., 2014). It was developed to address the current gap in environmental assessment methods by being a rapid, multi-dimensional assessment tool including various spatial and temporal scales[2] (Ran et al., 2015). The tool was developed to identify potential positive and negative environmental impacts of proposed practices or development interventions. The results highlight, in broad terms, the potential level of environmental impacts and identify "hotspots" of environmental impact.

The environmental impact is categorized into four key impact dimensions that are used as proxies to assess environmental change. Three dimensions, I) water, II) land/soil and III) biodiversity, are impacting the local environment, while the fourth, IV) greenhouse gas (GHG) emissions, is used to assess the contribution to global climate change (CC).

The tool uses pixel based modelling with spatial input data to generate output maps showing the distribution of environmental change in relation to baseline conditions. As such the CLEANED tool can be seen as a way

1 Comprehensive Livestock Environmental Assessment for improved Nutrition, a secured Environment and sustainable Development.

2 Fast in terms of developing parameters specific to a new study area, and in comparison to hydrological models, for example, which can require months of intensive fieldwork to calibrate and parameterise.

to give meaning to the many openly available but difficult to interpret GIS data for the context of transforming livestock value chains.

For each of the four environmental dimensions: i) a map illustrates the change between the baseline and the analysed future, and ii) for selected landscape scale indicators results are also presented in the form of a relative change to the baseline, i.e. consumptive water use in a scenario compared to the consumptive water use in the estimation of the current situation (baseline). In addition, measures of change in livestock productivity are also given. It is important to remember that CLEANED assesses relative change, thus the absolute numbers of environmental impacts or productivity change are only indicative.

The CLEANED model focuses on environmental impact of livestock value chains associated with feed production, which constitutes the major source of environmental impacts related to livestock value chains (Steinfeld et al., 2006; Fraval, 2014).

The four environmental impact dimensions are modelled based on the following criteria:

Water use is assessed by calculating crop and grass water requirement for the feed and fodder consumed by the analysed livestock production systems. Because the major water impact is resulting from feed and fodder consumed by the livestock, water impact is computed by comparing the water needed to produce the feed and fodder consumed by the livestock with the annual rainfall. The water needed is based on location specific evapotranspiration for each feed and fodder item. Crop water requirements are obtained from FAO's Global Agro-Ecological Zones (GAEZ) spatial layers of crop-specific actual evapotranspiration for low-input rainfed crops (mm) (GAEZ, 2012). Livestock energy requirement is estimated using equations for net energy requirements for cattle (IPCC, 2006, p10.15-10.18, based on National Research Council, 1996).

Greenhouse gas emission estimates are based on IPCC Tier 2 (IPCC, 2006) methodology and includes emissions from enteric fermentation, manure management, feed and fodder production and land use change for feed and fodder production.

Biodiversity measures are based on the International Union for Conservation of Nature and Natural resources red list of endangered species (IUCN, 2017). A species richness index is computed to show where most endangered species are located allowing to identify biodiversity hotspots. In the case of a land use change, the tool computes how many species that are critically endangered lose a piece of their habitat.

For the soil pathway, the input-output flow of nitrogen is calculated for each pixel, serving as a proxy for soil health based on the assumption that a positive balance (more nitrogen being added to the soil than is being removed) contributes to a healthy soil. The inflow of nitrogen consists of manure and fertilizer that is added to the soil, atmospheric deposition, and biological fixation. The nitrogen output consists of nitrogen absorbed by the feed and fodder, erosion, nitrogen leaching, and gaseous losses.

The CLEANED model is spatially explicit and integrates a range of open access geographical data, namely: evapotranspiration for different crop types, suitability and yields of different crop types and climate data (Global Agro-ecological Zones, GAEZ, http://www.fao.org/nr/gaez/en/), various soil related maps (Africa Soil Information Service, AFSIS, http://africasoils.net/), land cover (SERVIR-Global, https://servirglobal.net/ or Sahara and Sahel Observatory, OSS, http://www.oss-online.org/rep-sahel), greenhouse gas relevant maps (IPCC), making the model easily adjustable to any site.

To be as specific as possible, the input data for CLEANED should preferably be of high resolution and validated for the area of analysis. In particular, the land cover information is of great importance for the model outcome since it determines areas where animal feed and fodder may be produced, thus areas of potential environmental concern. To model future scenarios, land use change can also be modelled in CLEANED. These must be developed individually for each site of analysis and consider local expert knowledge and data to provide relevant data that can be discussed in stakeholder participatory workshops.

A detailed technical manual describing the CLEANED equations will be made available, together with the CLEANED tool for Tanzania by early 2019.

To provide useful output, the CLEANED tool has been combined with participatory stakeholder workshops. The participation of local stakeholders is vital to improve the local relevance of the output, both to ensure that the local context and dynamics are captured correctly in the input to the model and to build credibility and understanding, co-generating knowledge around potential environmental impacts associated with sustainable transformation and aid stakeholders in planning and decision making.

A baseline participatory workshop with identified stakeholders that are representative for the area of analysis was organized to gather input data for existing livestock systems and provide input to the baseline scenario in the CLEANED modelling. This data describes the livestock production systems and agricultural practices dominating the area of interest, and any environmental issues in the area that are currently of concern to the stakeholders, or may be in the future.

The ResLess process

In addition, as part of the ResLeSS process, participatory workshops have been organized to explore the outputs of the tool once parameterised for the area of interest, to validate the results in the context of local expert knowledge of systems that are not captured in the model, such as market networks and socio-economic conditions. Stakeholders can then explore trade-offs and synergies implied by different interventions and build consensus for a desirable future. In such an exercise, stakeholders compare and adjust the scale and mode of future livestock production systems and agricultural practices to meet various demands, which include environment and goals for productivity, economic development, livelihood opportunities and gender equality.

2.2 Interpreting and using CLEANED outputs

2.2.1 A representation and simplification of the real world

Any application of CLEANED is just a model, and as such it is just a simplification of reality. The initial parameterization of a CLEANED tool for a new study area, henceforth referred to as the 'base run', is therefore a simplified virtual landscape that tries to represent the reality on the ground as far as possible, i.e. by using the most accurate and realistic dataset possible for the user. But it is not possible (or necessary) to reproduce all the complexity of reality, and the base run remains a sort of "virtual landscape" with features that are inspired by the information obtained from literature, the reconnaissance tour, key informants and Workshop 1, which in turn (preferably) represent the features that are seen to be important and relevant by the stakeholders.

The CLEANED tool then computes the different environmental impacts of any scenario relative to this base run, i.e. the representation of reality developed for the CLEANED tool in that specific case study. This is because any bias or uncertainties in the initial parametrization (i.e. due to missing information or errors in representation) will then also be present in the scenarios. So, by computing the difference between the scenario and the base run, the bias is accounted for.

For other applications of CLEANED, to another context or to answer different questions, the parameterization would need to be adjusted to that context, and would contain a different set of important and relevant features extracted from literature, consultations and expert knowledge to represent a slightly different reality. Two different applications of CLEANED, i.e. different parameterisations, can then only be compared in term of relative change from their respective base runs and not in terms of absolute level of impact, as these levels are rooted in a different 'reality'.

A useful way of producing comparable results is to record the rationales used to design the scenarios in each application of CLEANED, and the evaluation of the associated impacts. As the user explores the assumptions and the constraints in the context of that 'reality', they will identify patterns and relationships, storylines of possible change in production and associated impact. The storylines identified by the user can be used to link results from an application of CLEANED to other models or across different applications (i.e. different 'realities') of CLEANED.

2.2.2 Sensitivity and non-linearities

In its current version of code development, a CLEANED tool is a set of linear and non-linear equations. An initial module computes the meat and milk production of the scenario and the land used to produce the feed and fodder to support this meat and milk production. This land requirement module is computed first and then each of the environmental impacts is computed independently, based on the first computations. As such there are no interactions between the different impacts, and therefore there are no self-reinforcing dynamics.

Yet, there are non-linear dynamics in the model, mainly driven by the different energy requirements of the different production categories, which are a function of the animal weight, the production per animal and the feed basket. In this way, the non-linearities that drive the model are defined by the assumptions of productivity gains that are possible by changing the feedbasket and breed. The vignettes produced for the CLEANED tool for Lushoto, Tanzania are one example of describing a set of plausible changes in production for Lushoto, which are underpinned by assumptions of productivity gains (see Section 3.4, and accompanying report, (Pfeifer et al., 2018)). This set of plausible vignettes was developed to be used by a non-expert audience in a workshop setting. It was critical to develop the vignettes carefully so that they would credible to those who would use the tool, as the set of vignettes defines what choices a non-expert user can test and combine into scenarios for future change. If the vignettes are unrealistic for the context, the evaluation and negotiations of future scenarios in the livestock transformation game will be meaningless, or in the worst case misleading, in identifying potential ways to alter livestock production in the future.

3 CLEANED in Tanzania

The area of interest is Lushoto District, on the border with Kenya, containing the Usambara mountains as well as the southern portion of Mkomazi National Park. Lushoto is one of eight districts in Tanga region, Tanzania. Lushoto is a high potential area, supplying vegetables to Dar es Salaam. The focus is on the smallscale dairy cattle livestock population of Lushoto District.

Assumptions in modelling CLEANED for Tanzania:

- CLEANED Tanzania is focusing on lactating animals only and does not account for animals kept for other purposes nor the follower animals.
- CLEANED only calculates the impact of local resources consumed for the animals in the study area (see Section 3.1 Boundaries for more detail). This means that the impact of feed that is imported is not calculated.
- Although CLEANED calculates impact on an annual basis, i.e. the impact of the animals in Lushoto over one year, there is a seasonality computation that accounts for the cropping seasonality. (see section 3.3 Seasonality for more detail):
  - the feed basket changes with the cropping season, so that there is a feed basket for the wet season and a feed basket for the dry season.

3.1 Boundaries of the study area

The CLEANED tool accounts for the feed and fodder production for the animals that are in the study area. The choice of boundary for the study area is therefore important. The CLEANED tool is sensitive to the boundaries, because several of its metrics are calculated based on the whole area within the study area boundaries, such as total potential biomass available for feed and fodder (to give an indication of when the local net primary production limit is reached and further demand would need to be satisfied by imports) and the volume of water used by livestock as a proportion of total annual rainfall falling over the study area.

The choice of boundaries was based on an ongoing value chain program at ILRI funded by the livestock CRP, boundaries that were confirmed to be relevant at the first workshop and the consultation with local experts following the first workshop. Because CLEANED computes the resource available for the livestock sector, the protected area, namely the national park was cut out of the boundary (red line in map Figure 1).

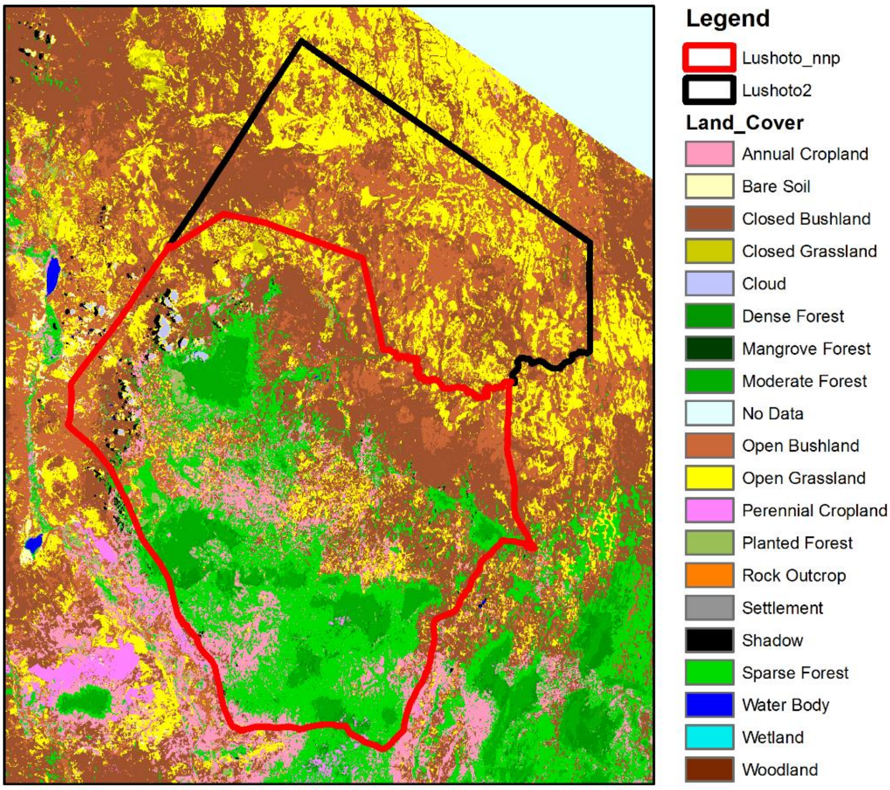

Figure 1: Study area boundaries for the dairy cattle population of Lushoto District, Tanga Region, Tanzania

3.2 Livestock production in Lushoto

Based on the activities in the first workshop, the research team characterised the livestock production in Lushoto into three categories, extensive lowland, semi-intensive highland and intensive highland. Yet, discussion about future developments in the first ResLess workshop have pointed out that in all three systems smallholders are trying to improve the breeds and the management systems. These breeds would be pretty similar across all systems. The geography is not a key driver in the up-coming changes, it had only emerged in the first workshop because of the participatory mapping exercise. This is why the CLEANED Tanzania was parametrized with breeds, namely preliminary local breeds, cross breeds (with 65-85% exotic genes), almost pure breed (more than 85% exotic breed). This classification is in line with ILRI results (AgriTT, 2017).

Local breeds are mainly found in the lowlands and are mainly fed on natural grasses and some crop residue. The cross-breeds are found in the highlands and are mainly fed on a mix of natural grass, crop residues and a bit of concentrate. In this system the main issue is the feed shortage in the dry season, which can be addressed with the production of hay and silage. Also planted feed, which has higher nutritional value than crop residues could be used to improve milk productivity per cow. The almost pure breed is a category is only marginally existent in Lushoto in the current situation. These animals need much more care and hardly feed on natural grasses and crop residues, but mainly on planted fodder and concentrates.

3.2.1 Initial livestock numbers per production category

The present-day cattle livestock population is the starting point for the CLEANED tool for Lushoto, a ‘base run’ that is a simplified representation of the current situation. Scenarios describing alternative patterns of livestock production in Lushoto are compared against this base run, so that CLEANED provides an indication of change in environmental impact compared to the present-day situation.

The initial animal's numbers in the three categories, local breed, cross-breed and almost pure breed for the base run assumed that the almost pure breeds are only marginally present in the area currently and therefore was set at zero.

As a result, only local and cross-breed animals had to be initialized. Two sources of data were explored for the initialization, the Demographic Health Survey (DHS) data for 2015 and the official statistics provided by the Lushoto district council.

The DHS data differentiates between dairy and non-dairy animals. Yet, the data for the Lushoto was too little (less than 30 observations), for a credible statistical inference and the data for the Tanga region too heterogenous to draw conclusions for Lushoto, which is the only highland within the whole region.

The Lushoto district census data for 2008 and 2017 was available and splits the livestock population into indigenous local breed and dairy cows that generally are cross-breeds. Yet the 2008 data also contains information about how many animals are lactating, information that is missing from the 2017 data.

Because CLEANED focuses only on lactating cows, both statics were combined (Table 1). Percentage of lactating cows were computed based on 2008 data, also it was assumed that there has been improved herd management in the cross breeds, and a 20% improvement in the percent of lactating animals in this category was assumed.

Table 1: Number of animals in the baseline scenario in Lushoto Tanzania

Category	Census data 2017	Lactating percentage 2008	Assumed lactating percentage 2018	Induced number of lactating animals	Cleaned 'baseline'
Local breed	84 132	29.77%	29.77%	25 045	25 000
Cross breed	33 566	36.98%	44.37%	14 894	15 000
(mostly) Exotic breed	-	-	-		0

3.3 Seasonality for Lushoto Tanzania

Seasonality in the tool is based on the FEAST report (Mangesho et al., 2013) suggesting that there are two rainy season, the long rainy season from February to June and the short rains from October to December. The other months were considered as dry.

3.4 Vignettes – storylines of plausible change

Vignettes are credible combinations of feed baskets with animal productivity for each animal category representing different livestock management options within each production category (Table 2). These vignettes are pre-set within the code, so that the non-expert can develop credible scenarios (that is, combinations of vignettes defining the production across the landscape). These vignettes were defined based on a literature review about livestock productivity and breeds in Tanzania. The initial numbers from the literature were reviewed by a feed and fodder expert who developed the full parameterization of these vignettes and ensured that the feedbasket entered into CLEANED is credible and based on nutrition available in Lushoto (see full details in Appendix 6.2).

Table 2: Vignettes and their descriptions. A total of 9 vignettes comprise the current version of each production category (three vignettes) and two alternative futures for each category (six vignettes).

	Code	Description
Local Breed (L)	LBR: Baseline (current state)	Current way of keeping local breed dairy animals, relying on grass and crop residues only
	L1: somewhat improved	Local breed dairy animals, kept extensively, fed little planted fodder and little concentrates (bran and oil seed cake), with hay and silage in dry season
	L2: much improved	Good quality local breed dairy animals, fed some planted fodder and little concentrates (bran and oil seed cake), with silage in the dry season
Cross Breed (Cb)	CBR: Baseline (current state)	Current cross-breed dairy animal, fed little planted fodder and little concentrates (bran and oil seed cake), with little hay in dry season
	C1: somewhat improved	Cross-breed dairy animals, fed some planted fodder and some concentrates (bran and oil seed cake), with hay and silage in dry season
	C2: much improved	High-quality cross-breeds, are fed an optimum amount of planted fodder and concentrates (bran and oil seed cake) with hay and silage in the dry season
Mostly Exotic Breed (E)	EBR: Baseline (current state)	Current specialised dairy production with 'mostly exotic' breeds, fed on some planted fodder and little concentrates (bran and oil seed cake), with hay and silage in the dry season
	E1: somewhat improved	Intensive dairy production with 'mostly exotic' breeds, fed mainly on planted fodder and some concentrates (bran and oil seed cake), with hay and silage in the dry season
	E2: much improved	Intensive dairy production with 'mostly exotic' breeds, are fed an optimum of planted fodder and some concentrates (bran and oil seed cake) and hay and silage in the dry season
Land use change (x%)		Choose how much feed biomass you need (in terms of % of existing cropland), for which you want to convert to crop land. Cropland will be converted from any land use (excepted protected area and forests) based on proximity of already existing cropland and suitability for crop.
Crop productivity (+20%)		Increase crop and fodder yields by 20%. More manure and chemical fertiliser is applied to croplands.

3.5 Land cover

The land cover used is shown in Figure 1 and is the Tanzania Land Cover 2010 Scheme II from SERVIR (http://geoportal.rcmrd.org/layers/servir%3Atanzania_landcover_2010_scheme_ii).

To compute impact of the feed basket, CLEANED needs to assign each feed and fodder to land cover. Two broad land cover class for feed were created, cropland that account for the annual cropland class in SERVIR and grassland that accounts for closed and open grassland as well as closed and open bushland class from SERVIR. Crop residues planted crop and silage is assigned to the cropland class, whereas natural grass and hey is assigned to grazing land class

3.6 Modelling land use change

The Tanzania CLEANED tool has a land use change module that converts any convertible land use, for example forest and grazing land can be converted into cropland, based on distance to already existing cropland and suitability for cropland.

The user input to this land use change module is a percentage of biomass compared to the baseline that should be produced from newly converted cropland. As such this module return a map of cells that have to be converted to cropland. This is then returned into CLEANED that adjusts all other land cover layers and recomputes all impacts.

The conversion to cropland is based on the assumption that land near to existing cropland and that is suitable for crop will be converted first. Some land use has been set to not be convertible to cropland, such as urban area, waterbodies and bare soil and are excluded from the beginning. The conversion rule for cropland computes a 'suitability for change' measure based on an equal weight average between the normalized suitability for crop based on a GAEZ layer, and the normalized distance to cropland. Each convertible cell is then ranked in order of priority to be converted based on the suitability for change. The algorithm converts land until the biomass required is reached and returns the cells that have been converted to cropland.

4 Functioning of CLEANED tool for Lushoto

The CLEANED tool for Lushoto has a simple user interface in RShiny that allows the user to enter a new scenario to be tested, run the tool and view the results (Figure 2). A new scenario is designed by selecting a vignette for each of the three production categories and choosing how many animals have in that category. If the category has disappeared in a particular scenario, select any vignette and set the number of animals to 0.

Full results as produced by the CLEANED interface, rather than the abbreviated version presented in the workshop, can be found in Appendix 6.3 for the homogeneous stakeholder groups of Day 1, and in Appendix 6.4 for the mixed stakeholder groups of Day 2.

Metrics used in the Workshop 2 to give a quick idea of impacts to evaluate in the discussions were:

- Productivity impacts (per year): Milk produced (litres), Maize produced (tons), Cropland required (ha), Grazing land required (ha), Import (ha)
- Environmental impacts (per year): Total volume of water used by the herd (litres); total volume of water used per animal (litres); total volume of water used per litre of milk (litres); Total greenhouse gas emitted by the herd (kg CO_2-equivalents); Greenhouse gas emitted per head, and per litre of milk (kg CO_2-equivalents); Average nitrogen balance in soil (N in minus N out); Volume of manure produced by the herd (tons); and the number of endangered species losing critical habitat when there is a land use change.

For all impact results, which are presented as % change in impact from the base run, CLEANED also provides an automatic guide as to whether the change is low, medium or high, relative to the range of plausible change in impacts for the study area (based on plausible scenarios; Appendix 6.2). This assessment allows the users to gain a sense of the scale of change. The users can then make their own (subjective) evaluation of what this impact means to them, based on their knowledge of the context.

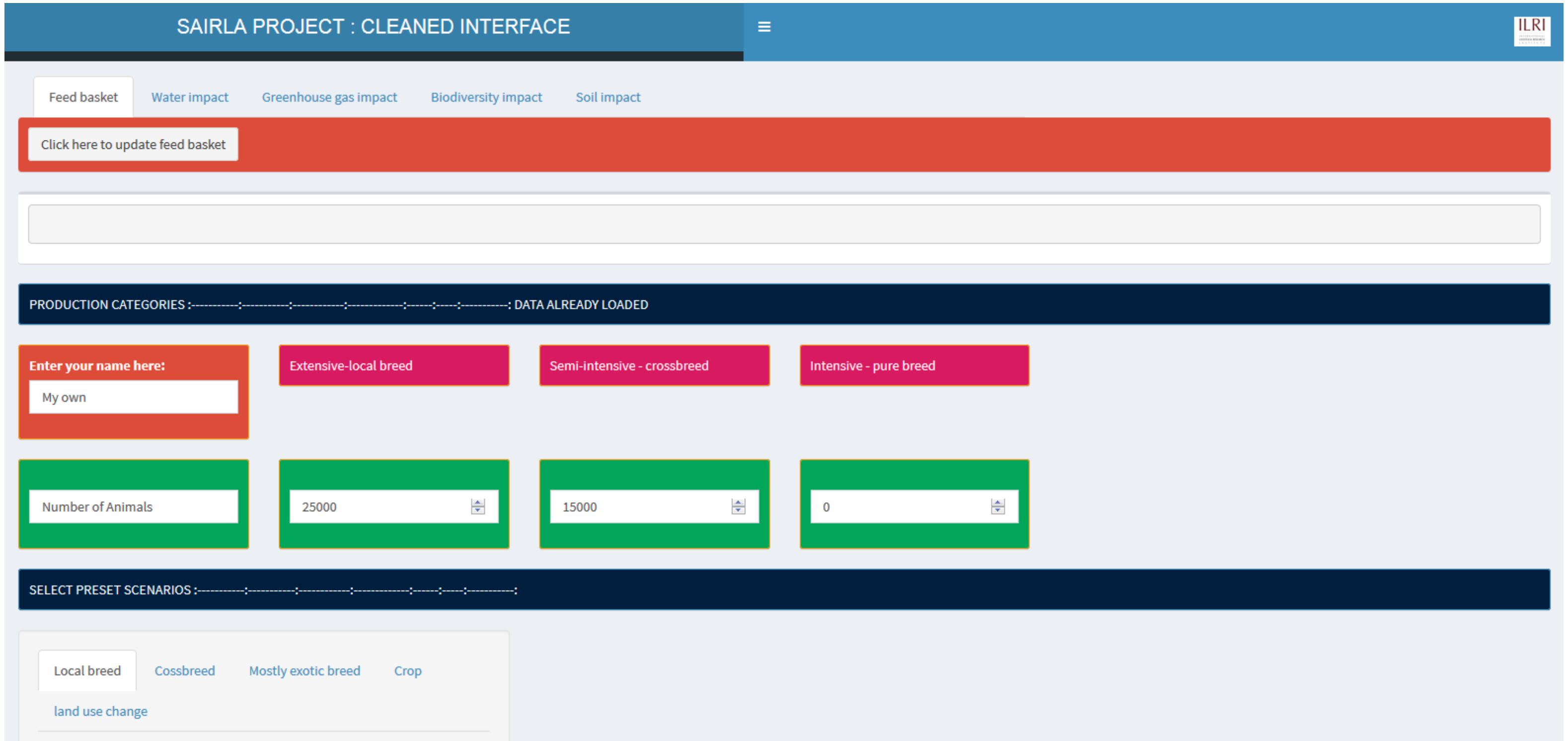

Figure 2: User interface for the CLEANED tool for Lushoto, Tanzania

5 References - update

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6 Appendix

6.1 The full vignette parametrization in CLEANED

Vignettes correspond to a combination of input variables in the CLEANED tool for Lushoto that are consistent, i.e. the productivity of an animal that is possible given the feed basket. The following table shows the parametrization of the vignettes in the CLEANED tool for Lushoto that were used during the Workshop 2 Transformation Game.

The final vignettes were cross-checked by a local feed and fodder expert.

		extensive system				semi-intensive system				intensive system				improved crop	
description		base run				base run				base run				base run	improved
name	Lvar	L0	L1	L2	Cbvar	Cb0	Cb1	Cb2	Evar	E0	E1	E2	Crvar	Cr0	Cr1
Alive weight (kg)	lwes	180	200	220	lwsis	220	230	250	lwis	250	275	300			
Milk production (kg/cow/year)	myes	500	1000	1500	mysis	2000	2100	2500	myis	2300	3000	3500			
Dressing percentage															
Feed basket dry season															
Natural grass	efng1	30	25	10	sfng1	20	10	5	ifng1	5	0	0			
Cereal crop residue	efrc1	70	58	46	sfrc1	45	30	10	ifrc1	15	5	0			
Rice crop residue	efrr1	0	0	0	sfrr1	0	0	0	ifrr1	0	0	0			
Legume crop residue	efrl1	0	5	5	sfrl1	12	5	5	ifrl1	10	5	0			
Planted fodder	efpf1	0	0	13	sfpf1	5	20	40	ifpf1	35	45	45			
Concentrate – bran	efconc1	0	1	3	sfconc1	5	10	10	ifconc1	15	15	15			
Concentrate – oil seed cake	efconos1	0	1	3	sfconos1	5	10	10	ifconos1	5	5	10			
Hay	efhay1	0	5	10	sfhay1	8	10	5	ifhay1	10	5	0			
Silage	efsil1	0	5	10	sfsil1	0	5	15	ifsil1	5	20	30			
Feed basket wet season															
Natural grass	efng2	98	96	94	sfng2	62	40	25	ifng2	25	5	0			
Cereal crop residue	efrc2	2	2	2	sfrc2	5	5	5	ifrc2	5	5	0			
Rice crop residue	efrr2	0	0	0	sfrr2	0	0	0	ifrr2	0	0	0			
Legume crop residue	efrl2	0	0	0	sfrl2	5	0	0	ifrl2	5	0	0			
Planted fodder	efpf2	0	0	0	sfpf2	14	40	50	ifpf2	45	70	75			
Concentrate – bran	efconc2	0	1	2	sfconc2	9	10	10	ifconc2	15	15	15			
Concentrate – oil seed cake	efconos2	0	1	2	sfconos2	5	5	10	ifconos2	5	5	10			
Hay	efhay2	0	0	0	sfhay2	0	0	0	ifhay2	0	0	0			
Silage	efsil2	0	0	0	sfsil2	0	0	0	ifsil2	0	0	0			
Manure management															
% in lagoon	es_lagoon_perc	0	0	0	sis_lagoon_perc	0	0	0	is_lagoon_perc	0	0	0			
% as liquid slurry	es_liquidslurry_perc	0	0	0	sis_liquidslurry_perc	0	0	0	is_liquidslurry_perc	0	0	0			
% as solid storage	es_solidstorage_perc	0	0	0	sis_solidstorage_perc	0	0	0	is_solidstorage_perc	0	0	0			
% as drylot	es_drylot_perc	0	0	0	sis_drylot_perc	0	0	0	is_drylot_perc	0	0	0			
% left on pasture	es_pasture_perc	80	80	80	sis_pasture_perc	10	10	10	is_pasture_perc	0	0	0			
% daily spread	es_dailyspread_perc	10	10	10	sis_dailyspread_perc	80	80	80	is_dailyspread_perc	90	90	90			
% in digester	es_digester_perc	0	0	0	sis_digester_perc	0	0	0	is_digester_perc	5	5	5			
% used as fuel	es_fuel_perc	3	3	3	sis_fuel_perc	3	3	3	is_fuel_perc	0	0	0			
% other management	es_other_perc	7	7	7	sis_other_perc	7	7	7	is_other_perc	5	5	5			
improve crop scenario															
percent of stored manure applied to cereals													manc	0.6	0.8
Fertilizer application kg/ha applied to cereals													fertc	0	20
exogenous yield productivity gain in percentage of cereal yield													pgc	0.02	0.22

6.2 Valuation of environmental impact in CLEANED

In order to generate an automatic score to indicate the relative scale of impact of the different scenarios, i.e. to define whether the change is low, medium or high with respect to plausible change in the study area, scenarios have been developed. The different scenarios define the range of plausible change. This range was cut into 3 equal intervals defining what would be scored as low, medium and high.

6.2.1 The developed scenarios

Forecast scenarios based on a partial equilibrium model IMPACT (Enahoro et al., 2018), show that by 2030 demand for milk in Tanzania will double, however part of that milk will be imported. The domestic production will have to increase by 50% compared to today.

The two scenarios developed were quite simple:

1. Animals in all categories are increased by 50% at current feeding strategy.
2. Animals in all categories are increased by 50% at their respective best feeding strategy.

6.2.2 Assigning the score to changes

The environmental indictors were computed for each scenario. The difference to the base run was computed in absolute values. The maximum of this absolute value provides the credible range for the scenarios. This range value divided by three is the threshold value that has been used, as shown in Table 3 below, where X is the absolute value of the difference between a scenario and the base run.

Table 3: Assigning an automatic score to changes in environmental impact

Condition	Score
X < threshold	Low
Threshold < X < 2*threshold	Medium
X > 2*threshold	High

This rule has been applied to each environmental indicator.

6.3 CLEANED output for the homogenous stakeholder group scenarios

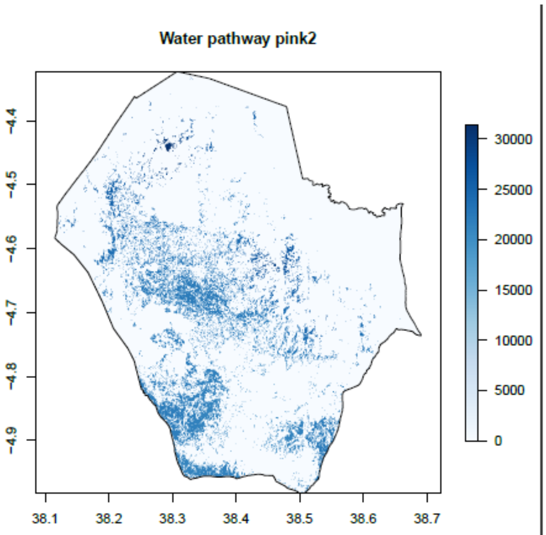
Detailed CLEANED results for the 4 scenarios from Day 1 – participants saw a selection of results, as described in Section 4.

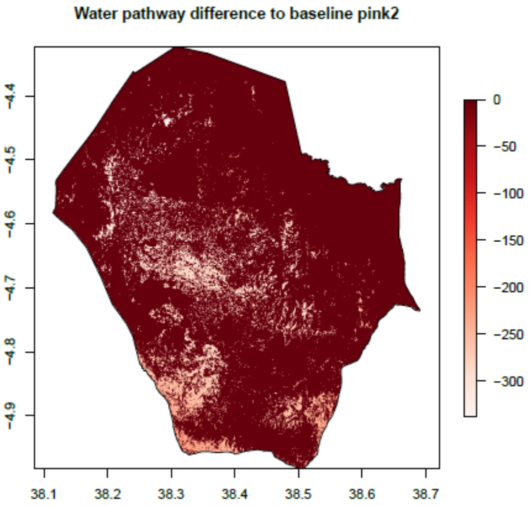
6.3.1 Farmers group 1 (Pink group)

Productivity

	result	diff	percent	evaluation
milk produced	50400.0	7900.0	18.6	low
tons of maize produced	751.0	−795.0	−51.4	high
total area available for crop	309.0	0.0	0.0	low
total area available for pasture	1395.0	0.0	0.0	low
crop area used	150.1	−149.7	−49.9	high
pasture area used	314.4	−337.5	−51.8	high
import crop	0.0	0.0	0.0	low
import pasture	0.0	0.0	0.0	low
total numbers of cows	25000.0	−15000.0	−37.5	high
local breed cow	8000.0	−17000.0	−68.0	high
cross−breed cows	14000.0	−1000.0	−6.7	low
pure breed cows	3000.0	3000.0	Inf	high

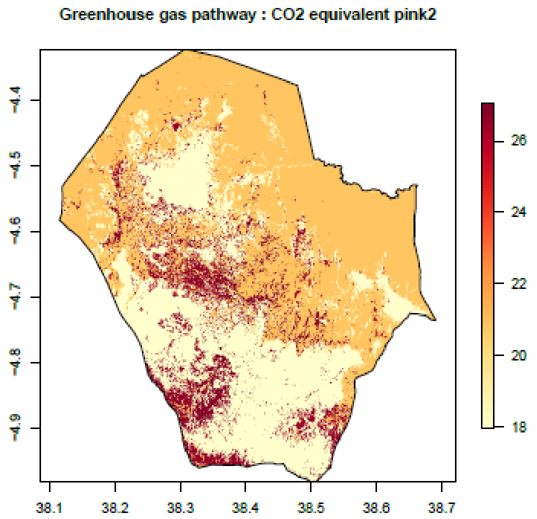
Water impact

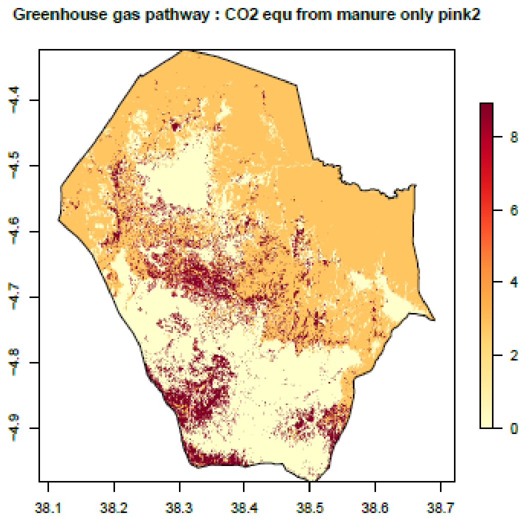


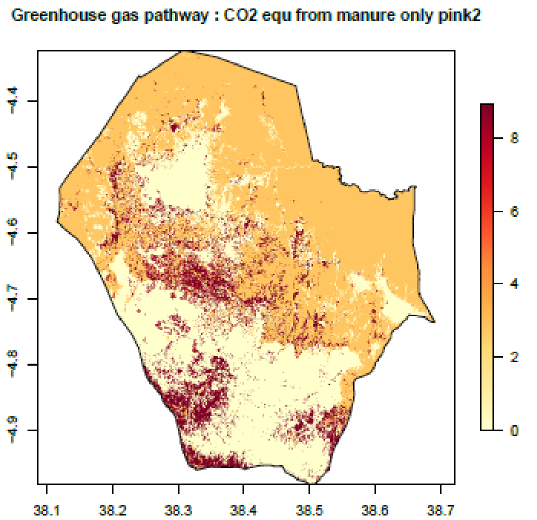


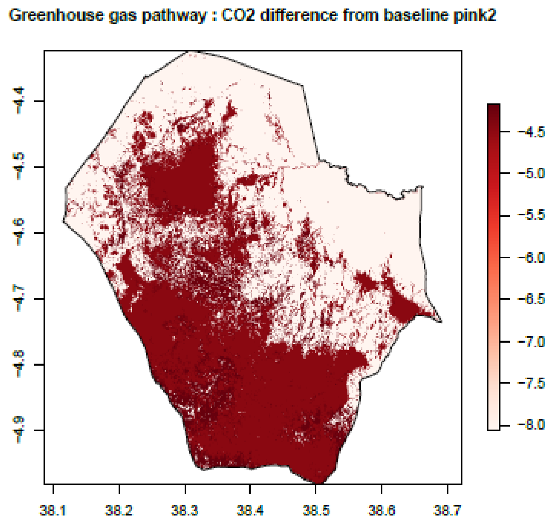
	result	difference	percent	evaluation
total water consumption	9.419698e+10	−1.141669e+11	−54.8	high
water consumption rainfall ratio	2.603000e+01	−3.156000e+01	−54.8	high
water consumption per cow	3.767879e+06	−1.441218e+06	−27.7	high
water consumption per ton of milk	1.868988e+06	−3.033691e+06	−61.9	high
average water consumption intensity	2.554700e+01	−3.097300e+01	−54.8	high

Greenhouse gas emissions







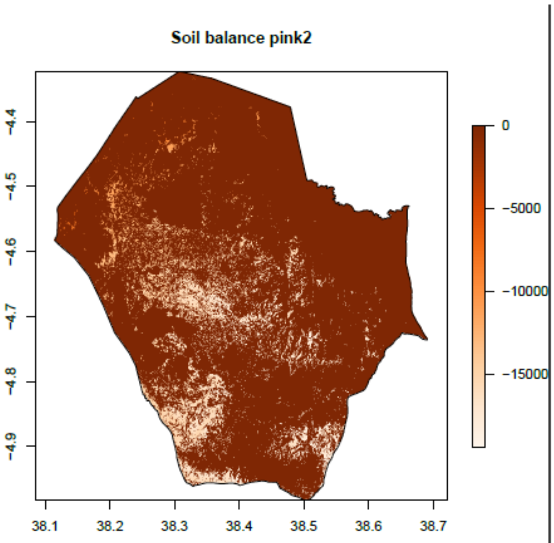


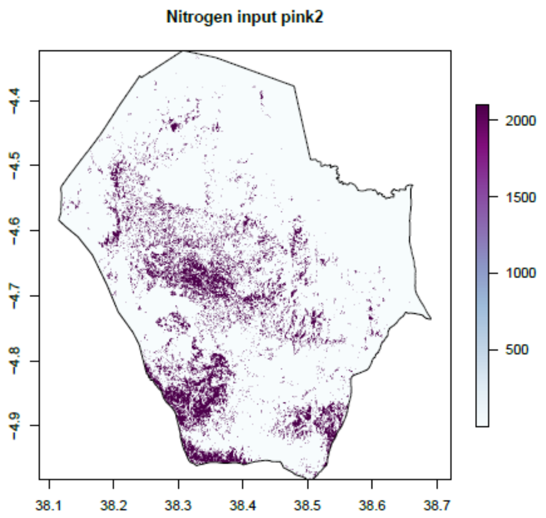
	result	difference	percent	evaluation
CO2 emmissions	62462270	−19138551	−23.5	medium
CO2 from manure	7395180	−5530216	−42.8	high
CO2 from interic fermetation	55074863	−13608335	−19.8	medium
CO2 per cow	2498	458	22.5	high
CO2 per tonnes of milk	1239	−681	−35.5	high

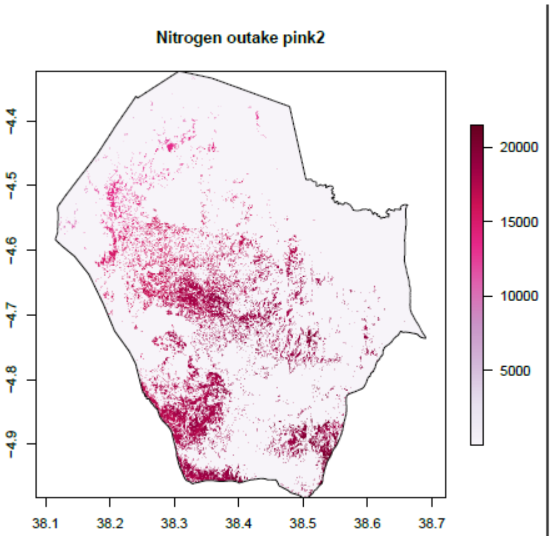
Biodiversity

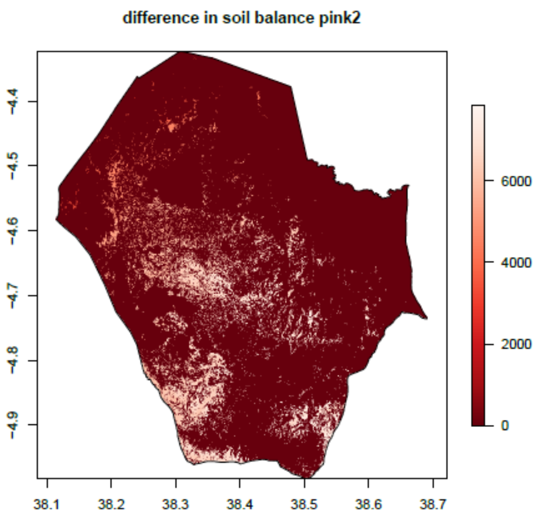
Same as Farmers group 1

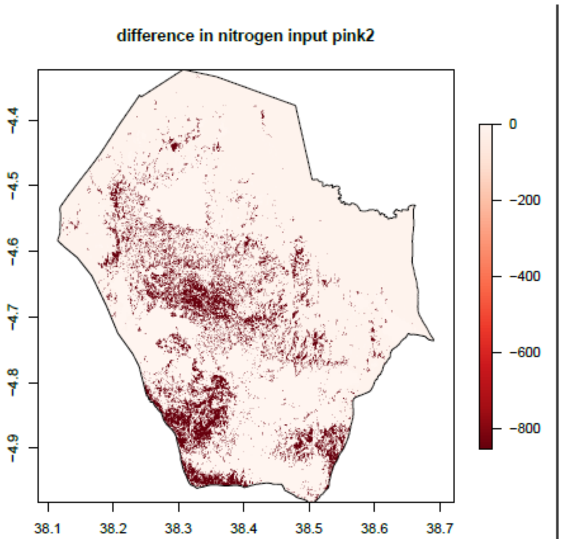
Soil health

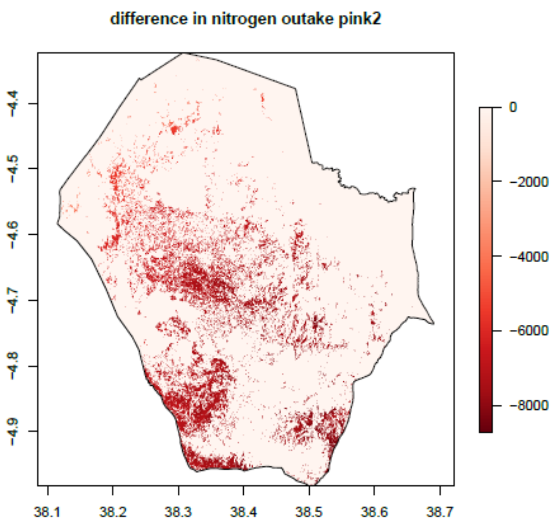

Soil balance pink2
-4.4 -4.5 -4.6 -4.7 -4.8 -4.9
38.1 38.2 38.3 38.4 38.5 38.6 38.7
0
-5000
-10000
-15000


Nitrogen input pink2
-4.4 -4.5 -4.6 -4.7 -4.8 -4.9
38.1 38.2 38.3 38.4 38.5 38.6 38.7
2000
1500
1000
500


Nitrogen outake pink2
-4.4 -4.5 -4.6 -4.7 -4.8 -4.9
38.1 38.2 38.3 38.4 38.5 38.6 38.7
20000
15000
10000
5000


difference in soil balance pink2
-4.4 -4.5 -4.6 -4.7 -4.8 -4.9
38.1 38.2 38.3 38.4 38.5 38.6 38.7
6000
4000
2000
0


difference in nitrogen input pink2
-4.4 -4.5 -4.6 -4.7 -4.8 -4.9
38.1 38.2 38.3 38.4 38.5 38.6 38.7
0
-200
-400
-600
-800


difference in nitrogen outake pink2
-4.4 -4.5 -4.6 -4.7 -4.8 -4.9
38.1 38.2 38.3 38.4 38.5 38.6 38.7
0
-2000
-4000
-6000
-8000

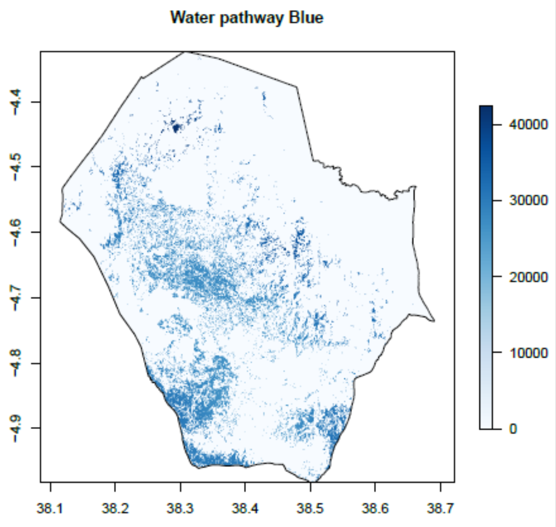
	result	difference	percent	evaluation
nitrogen balance	−5361155691	2175748279	−28.9	low
total nitrogen added	722793369	−293011004	−28.8	low
total manure produced	24455000	−10220000	−29.5	low

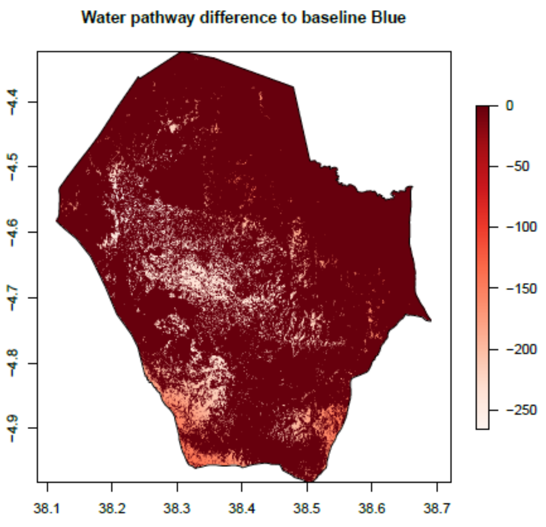
6.3.2 Farmers group 2 (Blue group)

Productivity

	result	diff	percent	evaluation
milk produced	85000.0	42500.0	100.0	medium
tons of maize produced	843.0	−703.0	−45.5	medium
total area available for crop	309.0	0.0	0.0	low
total area available for pasture	1395.0	0.0	0.0	low
crop area used	213.0	−86.8	−29.0	medium
pasture area used	319.1	−332.8	−51.1	high
import crop	0.0	0.0	0.0	low
import pasture	0.0	0.0	0.0	low
total numbers of cows	40000.0	0.0	0.0	low
local breed cow	10000.0	−15000.0	−60.0	medium
cross−breed cows	20000.0	5000.0	33.3	medium
pure breed cows	10000.0	10000.0	Inf	high

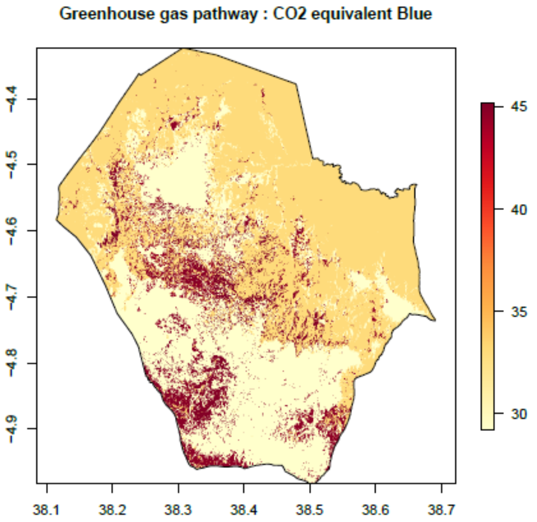
Water impact

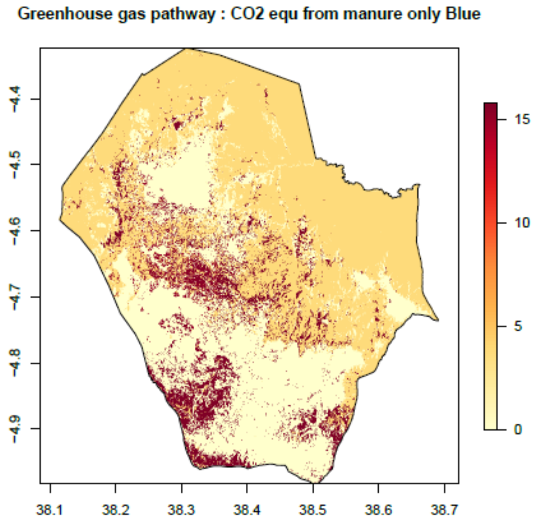


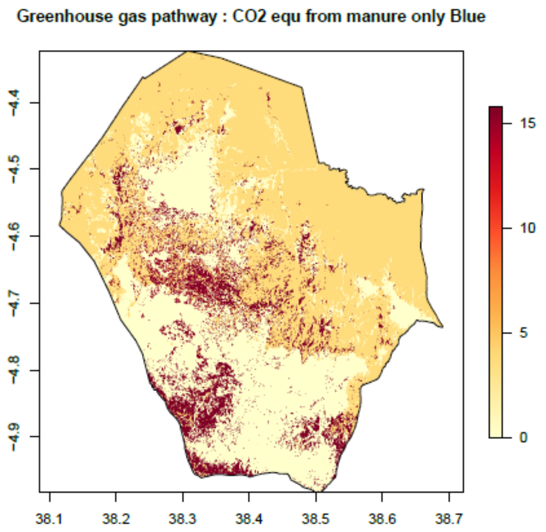


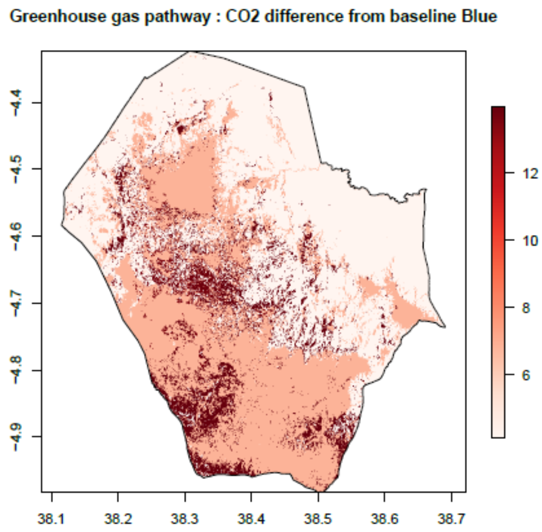
	result	difference	percent	evaluation
total water consumption	1.210635e+11	−8.730036e+10	−41.9	high
water consumption rainfall ratio	3.346000e+01	−2.413000e+01	−41.9	high
water consumption per cow	3.026588e+06	−2.182509e+06	−41.9	high
water consumption per ton of milk	1.424277e+06	−3.478402e+06	−70.9	high
ıverage water consumption intensity	3.282300e+01	−2.369700e+01	−41.9	high

Greenhouse gas emissions







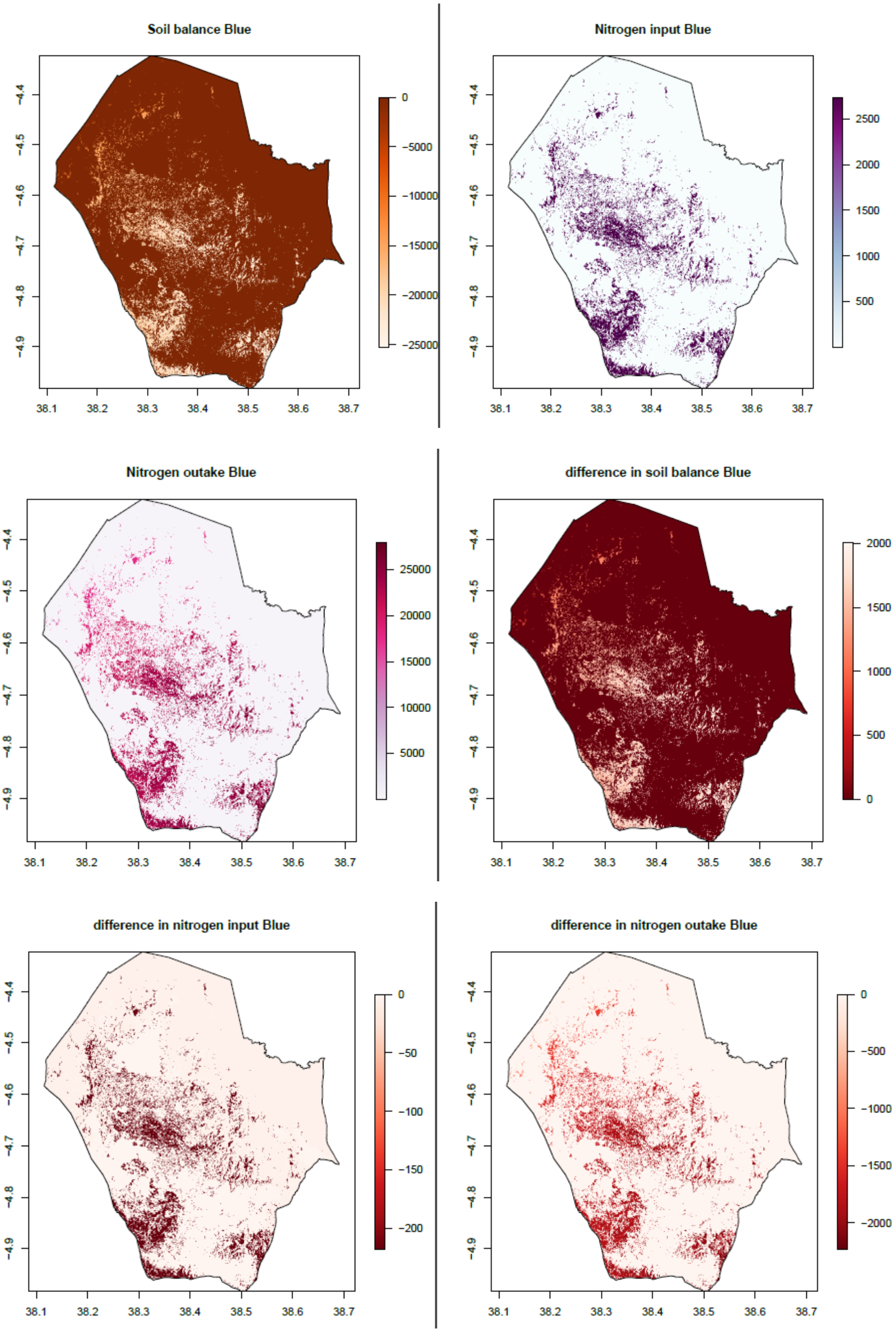


	result	difference	percent	evaluation
CO2 emmissions	100807892	19207071	23.5	medium
CO2 from manure	11173958	−1751438	−13.6	low
CO2 from interic fermetation	89641706	20958508	30.5	medium
CO2 per cow	2520	480	23.5	high
CO2 per tonnes of milk	1186	−734	−38.2	high

Biodiversity

Same as Farmers group 1

Soil health


Soil balance Blue
0
-5000
-10000
-15000
-20000
-25000
Nitrogen input Blue
2500
2000
1500
1000
500
Nitrogen outake Blue
25000
20000
15000
10000
5000
difference in soil balance Blue
2000
1500
1000
500
0
difference in nitrogen input Blue
0
-50
-100
-150
-200
difference in nitrogen outake Blue
0
-500
-1000
-1500
-2000
38.1
38.2
38.3
38.4
38.5
38.6
38.7
-4.4
-4.5
-4.6
-4.7
-4.8
-4.9

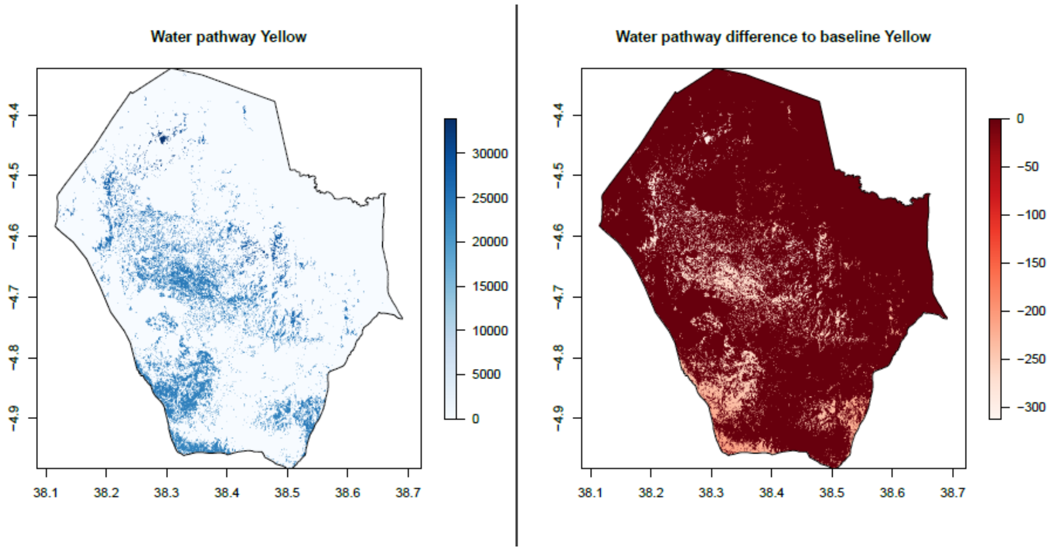
	result	difference	percent	evaluation
nitrogen balance	-6975410978	561492992	-7.4	low
total nitrogen added	940920946	-74883427	-7.4	low
total manure produced	40150000	5475000	15.8	low

6.3.3 Traders and processors (Yellow group)

Productivity

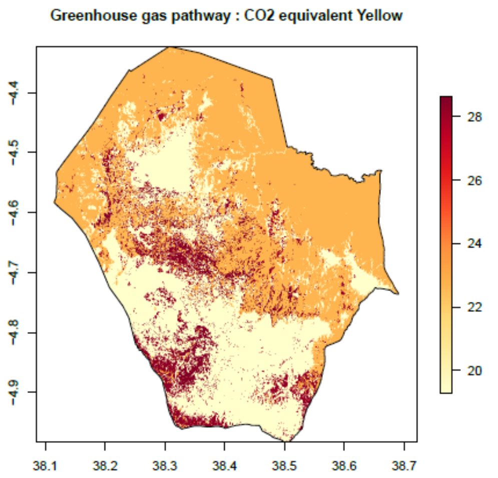
	result	diff	percent	evaluation
milk produced	53400.0	10900.0	25.6	low
tons of maize produced	823.0	−723.0	−46.8	medium
total area available for crop	309.0	0.0	0.0	low
total area available for pasture	1395.0	0.0	0.0	low
crop area used	161.5	−138.3	−46.1	high
pasture area used	356.5	−295.4	−45.3	high
import crop	0.0	0.0	0.0	low
import pasture	0.0	0.0	0.0	low
total numbers of cows	27000.0	−13000.0	−32.5	medium
local breed cow	10000.0	−15000.0	−60.0	medium
cross−breed cows	14000.0	−1000.0	−6.7	low
pure breed cows	3000.0	3000.0	Inf	high

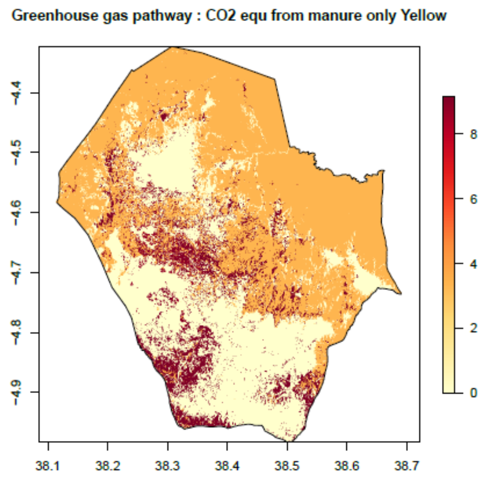
Water impact

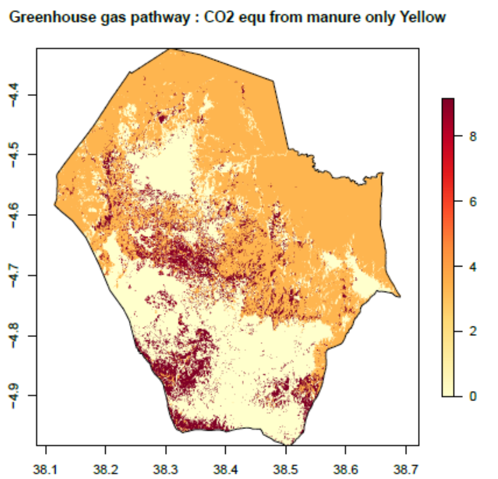


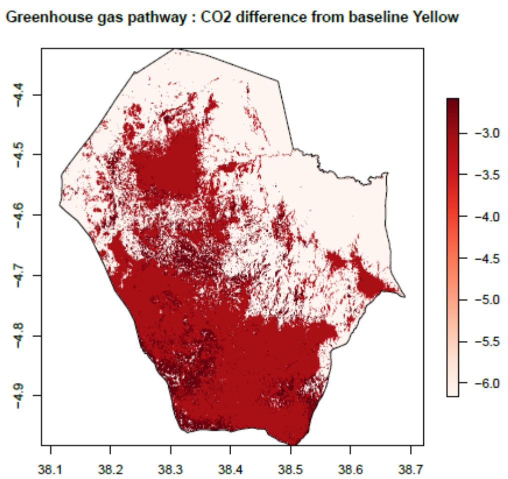
	result	difference	percent	evaluation
total water consumption	1.020242e+11	−1.063397e+11	−51.0	high
water consumption rainfall ratio	2.820000e+01	−2.939000e+01	−51.0	high
water consumption per cow	3.778675e+06	−1.430422e+06	−27.5	high
water consumption per ton of milk	1.910566e+06	−2.992113e+06	−61.0	high
verage water consumption intensity	2.767100e+01	−2.884900e+01	−51.0	high

Greenhouse gas emissions







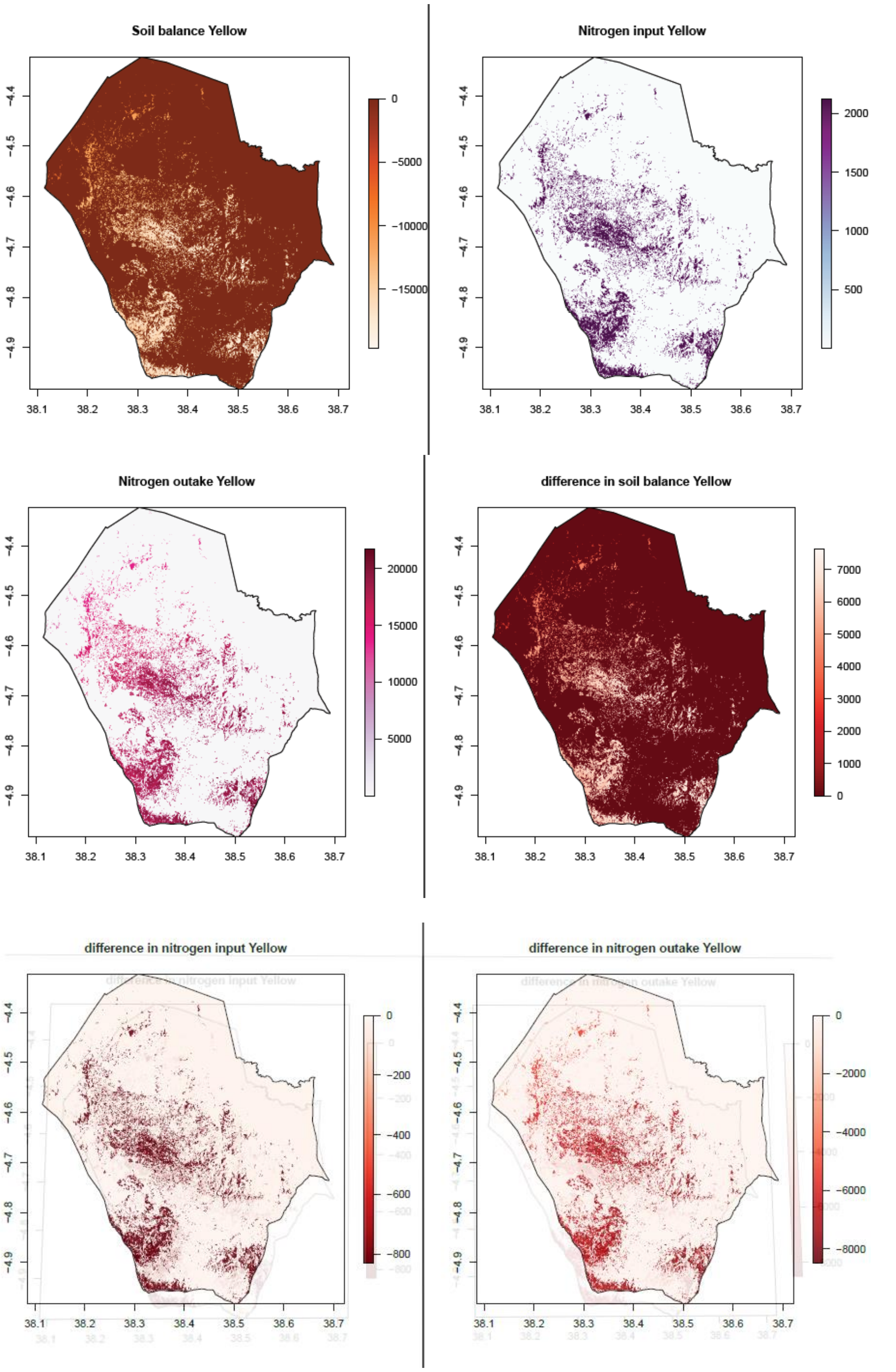


	result	difference	percent	evaluation
CO2 emmissions	67536980	−14063841	−17.2	medium
CO2 from manure	8352382	−4573014	−35.4	high
CO2 from interic fermetation	59192370	−9490828	−13.8	low
CO2 per cow	2501	461	22.6	high
CO2 per tonnes of milk	1265	−655	−34.1	high

Biodiversity

Same as Farmers group 1

Soil health



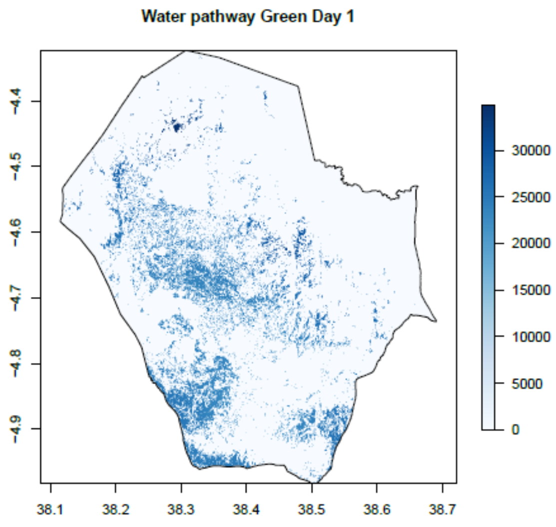
	result	difference	percent	evaluation
nitrogen balance	−5421993929	2114910041	−28.1	low
total nitrogen added	730888952	−284915421	−28.0	low
total manure produced	25915000	−8760000	−25.3	low

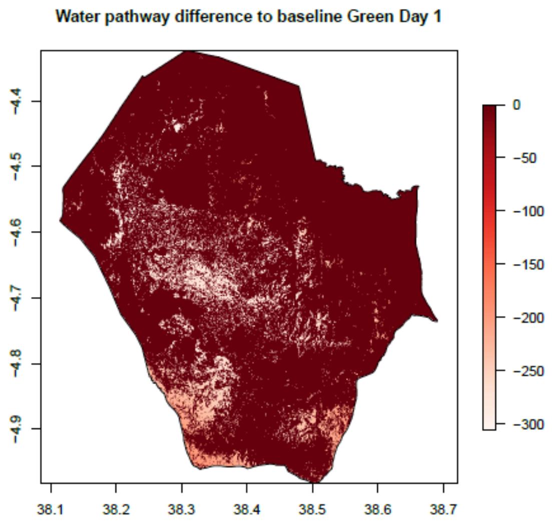
6.3.4 Local administrators and experts (Green group)

Productivity

	result	diff	percent	evaluation
milk produced	63000.0	20500.0	48.2	low
tons of maize produced	699.0	−847.0	−54.8	high
total area available for crop	309.0	0.0	0.0	low
total area available for pasture	1395.0	0.0	0.0	low
crop area used	171.5	−128.3	−42.8	high
pasture area used	341.1	−310.8	−47.7	high
import crop	0.0	0.0	0.0	low
import pasture	0.0	0.0	0.0	low
total numbers of cows	29000.0	−11000.0	−27.5	medium
local breed cow	12000.0	−13000.0	−52.0	medium
cross−breed cows	12000.0	−3000.0	−20.0	low
pure breed cows	5000.0	5000.0	Inf	high

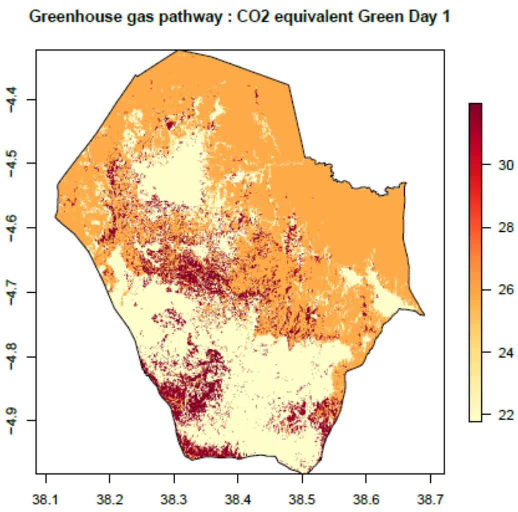
Water impact

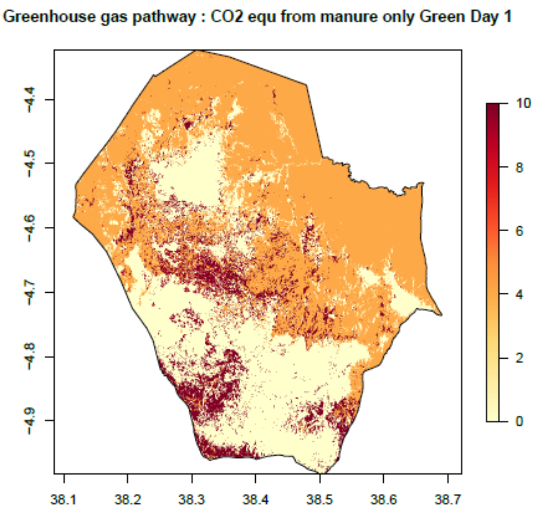


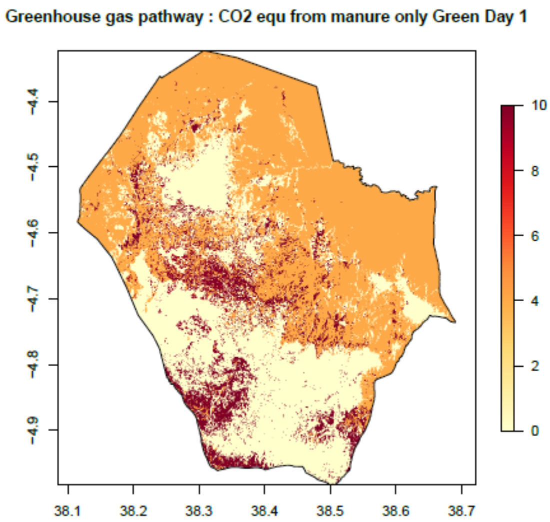


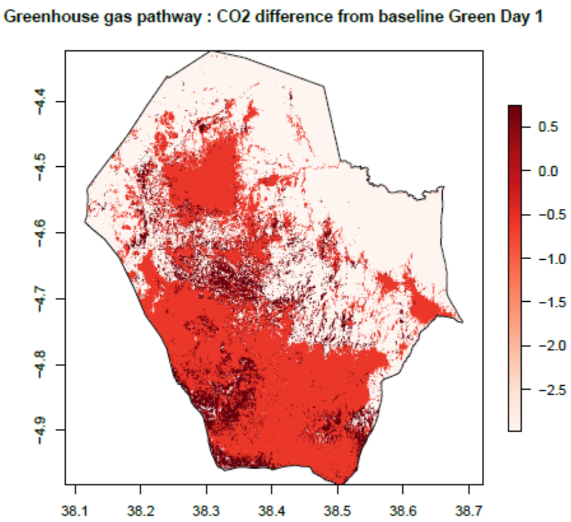
	result	difference	percent	evaluation
total water consumption	1.031424e+11	−1.052215e+11	−50.5	high
water consumption rainfall ratio	2.851000e+01	−2.908000e+01	−50.5	high
water consumption per cow	3.556633e+06	−1.652464e+06	−31.7	high
water consumption per ton of milk	1.637180e+06	−3.265499e+06	−66.6	high
average water consumption intensity	2.796800e+01	−2.855200e+01	−50.5	high

Greenhouse gas emissions









	result	difference	percent	evaluation
CO2 emmissions	76538627	−5062194	−6.2	low
CO2 from manure	9715293	−3210103	−24.8	medium
CO2 from interic fermetation	66831107	−1852091	−2.7	low
CO2 per cow	2639	599	29.4	high
CO2 per tonnes of milk	1215	−705	−36.7	high

Biodiversity

Soil health

6.4 CLEANED output for the heterogenous stakeholder group scenarios

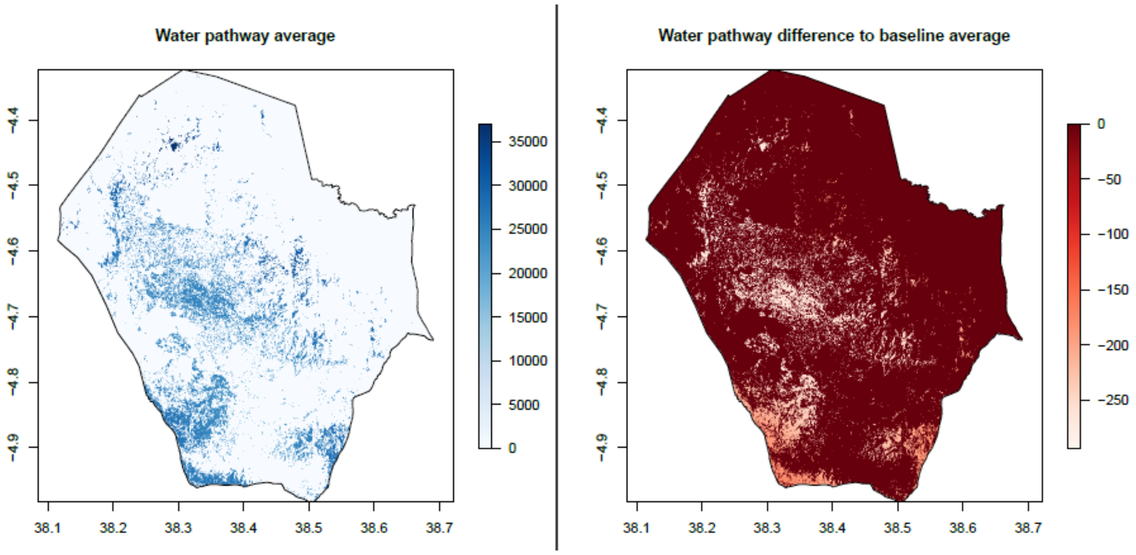
Detailed CLEANED results for the 5 scenarios on Day 2 – the starting scenario, which was an average of the four group scenarios from Day 1, and a first and second revised scenario from each of the two groups – not just the summary results used on the scorecards

6.4.1 Starting scenario : average

Productivity

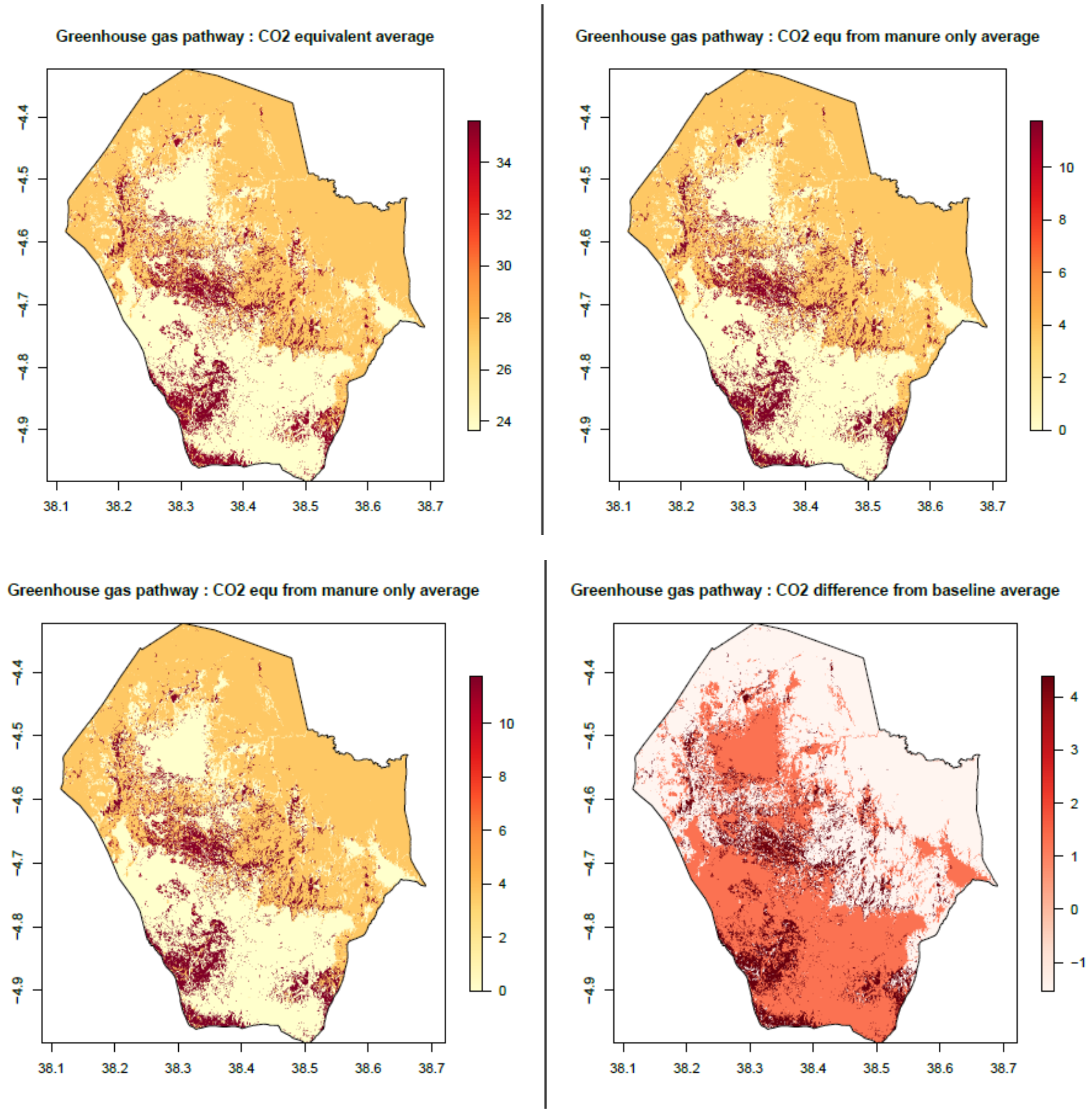
	result	diff	percent	evaluation
milk produced	70500.0	28000.0	65.9	medium
tons of maize produced	689.0	−857.0	−55.4	high
total area available for crop	309.0	0.0	0.0	low
total area available for pasture	1395.0	0.0	0.0	low
crop area used	184.5	−115.3	−38.5	high
pasture area used	320.9	−331.0	−50.8	high
import crop	0.0	0.0	0.0	low
import pasture	0.0	0.0	0.0	low
total numbers of cows	31000.0	−9000.0	−22.5	medium
local breed cow	10000.0	−15000.0	−60.0	medium
cross−breed cows	15000.0	0.0	0.0	low
pure breed cows	6000.0	6000.0	Inf	high

Water impact



	result	difference	percent	evaluation
total water consumption	1.085453e+11	−9.981854e+10	−47.9	high
water consumption rainfall ratio	3.000000e+01	−2.759000e+01	−47.9	high
water consumption per cow	3.501462e+06	−1.707635e+06	−32.8	high
water consumption per ton of milk	1.539650e+06	−3.363029e+06	−68.6	high
verage water consumption intensity	2.943100e+01	−2.708900e+01	−47.9	high

Greenhouse gas emission

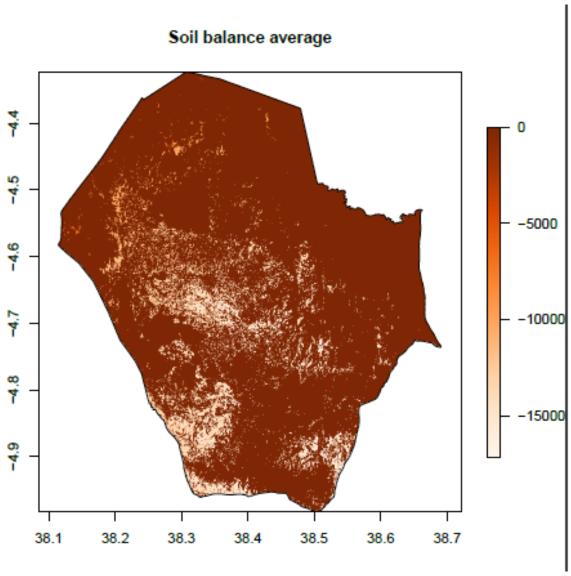


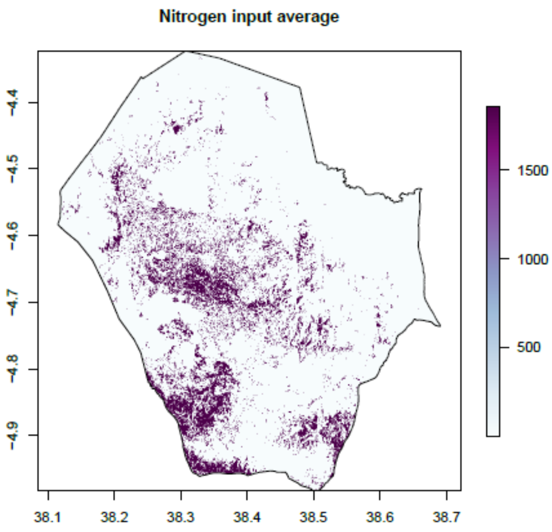
	result	difference	percent	evaluation
CO2 emmissions	82216759	615938	0.8	low
CO2 from manure	9643925	−3281471	−25.4	medium
CO2 from interic fermetation	72580607	3897409	5.7	low
CO2 per cow	2652	612	30.0	high
CO2 per tonnes of milk	1166	−754	−39.3	high

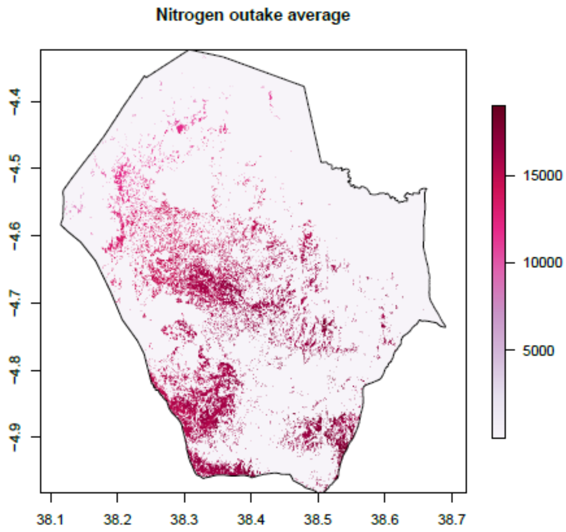
Biodiversity

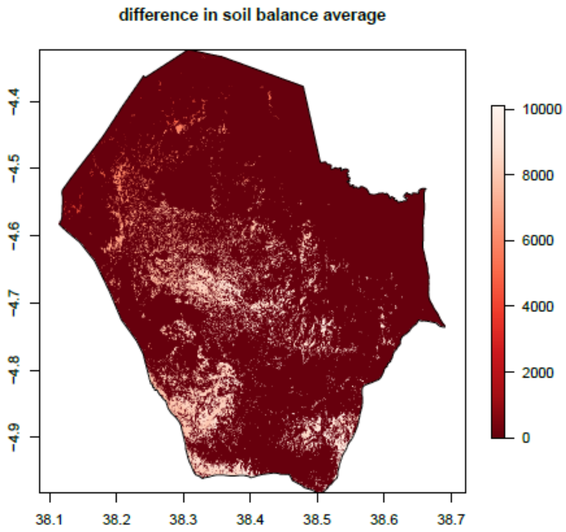
Same as Farmers group 1

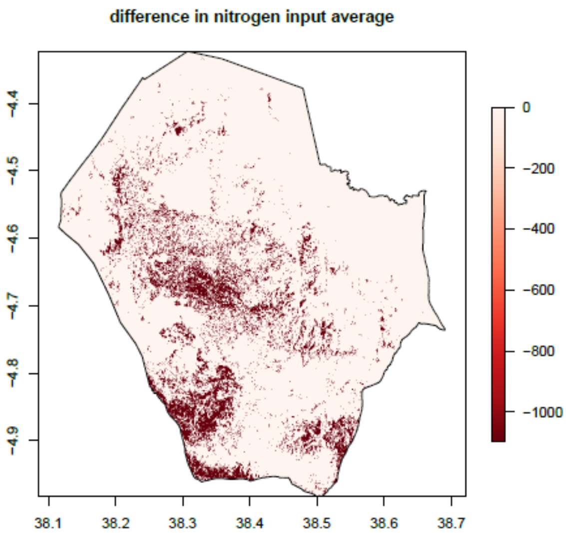
Soil health

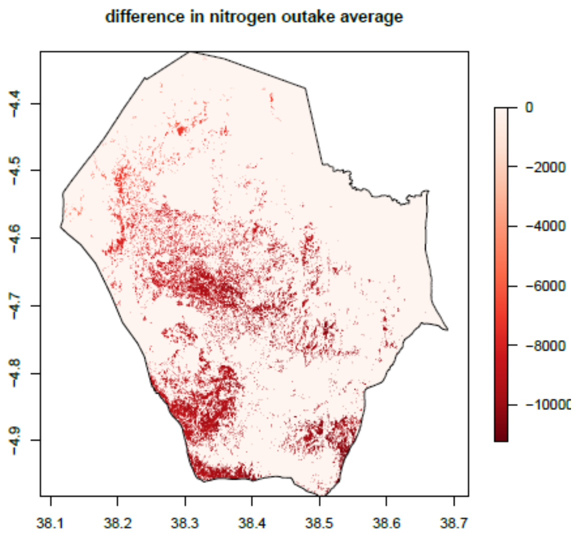

Soil balance average
0
−5000
−10000
−15000
-4.4
-4.5
-4.6
-4.7
-4.8
-4.9
38.1
38.2
38.3
38.4
38.5
38.6
38.7


Nitrogen input average
1500
1000
500
-4.4
-4.5
-4.6
-4.7
-4.8
-4.9
38.1
38.2
38.3
38.4
38.5
38.6
38.7


Nitrogen outake average
15000
10000
5000
-4.4
-4.5
-4.6
-4.7
-4.8
-4.9
38.1
38.2
38.3
38.4
38.5
38.6
38.7


difference in soil balance average
10000
8000
6000
4000
2000
0
-4.4
-4.5
-4.6
-4.7
-4.8
-4.9
38.1
38.2
38.3
38.4
38.5
38.6
38.7


difference in nitrogen input average
0
−200
−400
−600
−800
−1000
-4.4
-4.5
-4.6
-4.7
-4.8
-4.9
38.1
38.2
38.3
38.4
38.5
38.6
38.7


difference in nitrogen outake average
0
−2000
−4000
−6000
−8000
-4.4
-4.5
-4.6
-4.7
-4.8
-4.9
38.1
38.2
38.3
38.4
38.5
38.6
38.7

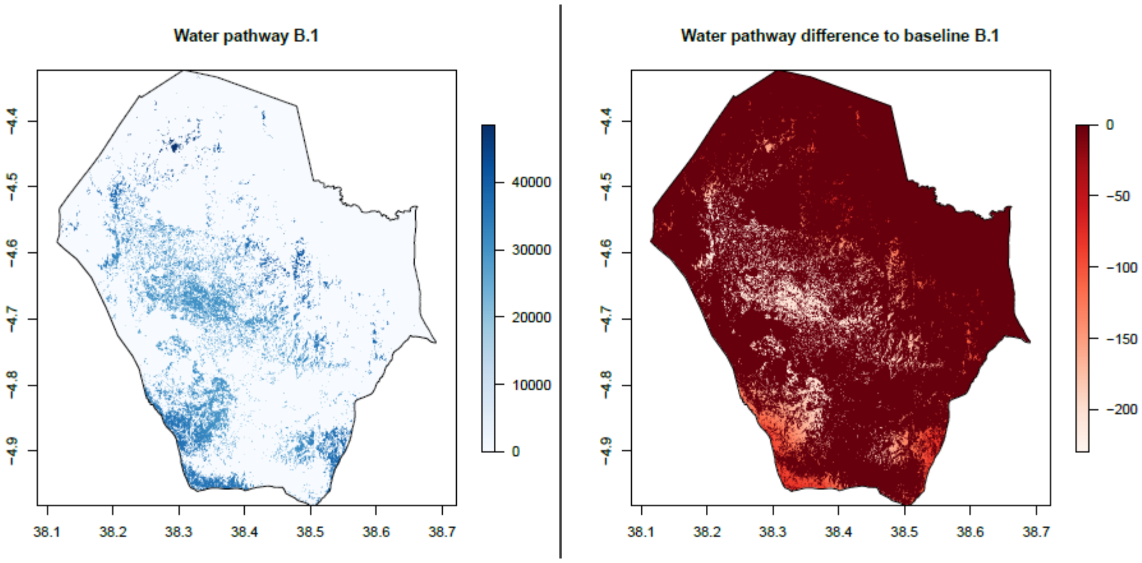
	result	difference	percent	evaluation
nitrogen balance	−4740876953	2796027017	−37.1	low
total nitrogen added	638954038	−376850335	−37.1	low
total manure produced	30295000	−4380000	−12.6	low

6.4.2 Group A: first scenario (B.1)

Productivity

	result	diff	percent	evaluation
milk produced	108000.0	65500.0	154.1	high
tons of maize produced	701.0	−845.0	−54.7	high
total area available for crop	309.0	0.0	0.0	low
total area available for pasture	1395.0	0.0	0.0	low
crop area used	251.4	−48.4	−16.1	low
pasture area used	236.8	−415.1	−63.7	high
import crop	0.0	0.0	0.0	low
import pasture	0.0	0.0	0.0	low
total numbers of cows	41000.0	1000.0	2.5	low
local breed cow	5000.0	−20000.0	−80.0	high
cross−breed cows	15000.0	0.0	0.0	low
pure breed cows	21000.0	21000.0	Inf	high

Water impact

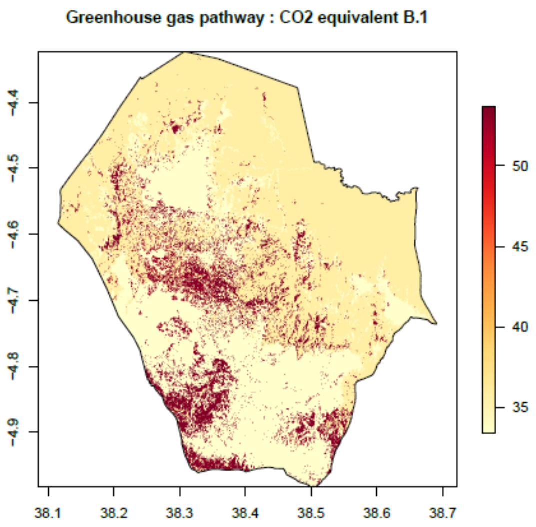


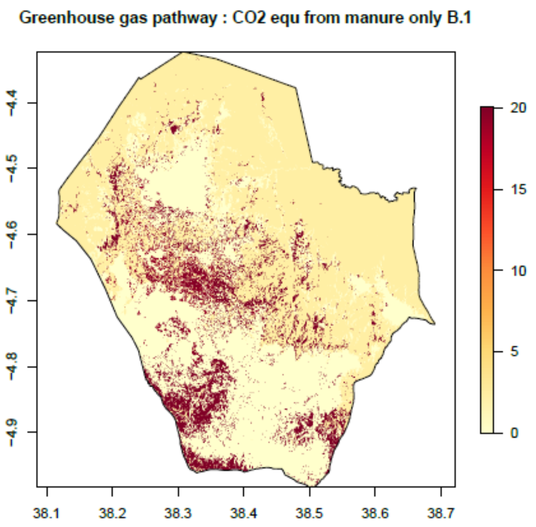
	result	difference	percent	evaluation
total water consumption	1.378555e+11	−7.050836e+10	−33.8	high
water consumption rainfall ratio	3.810000e+01	−1.949000e+01	−33.8	medium
water consumption per cow	3.362330e+06	−1.846767e+06	−35.5	high
water consumption per ton of milk	1.276440e+06	−3.626239e+06	−74.0	high
average water consumption intensity	3.736700e+01	−1.915300e+01	−33.9	high

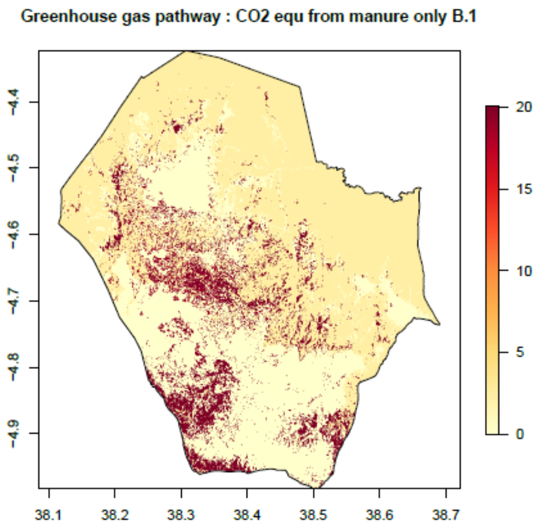
Biodiversity

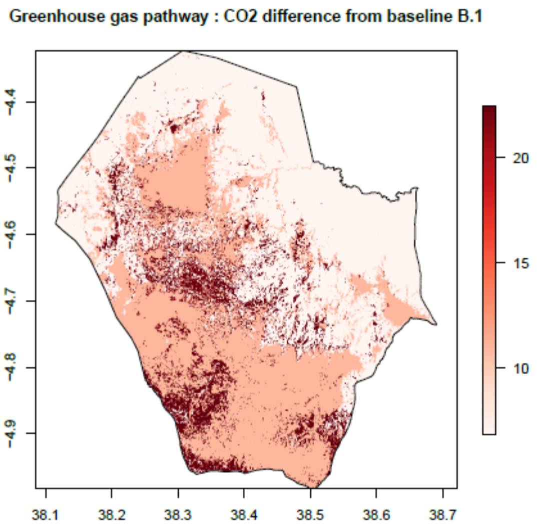
Same as Farmers group 1

Greenhouse gas emission







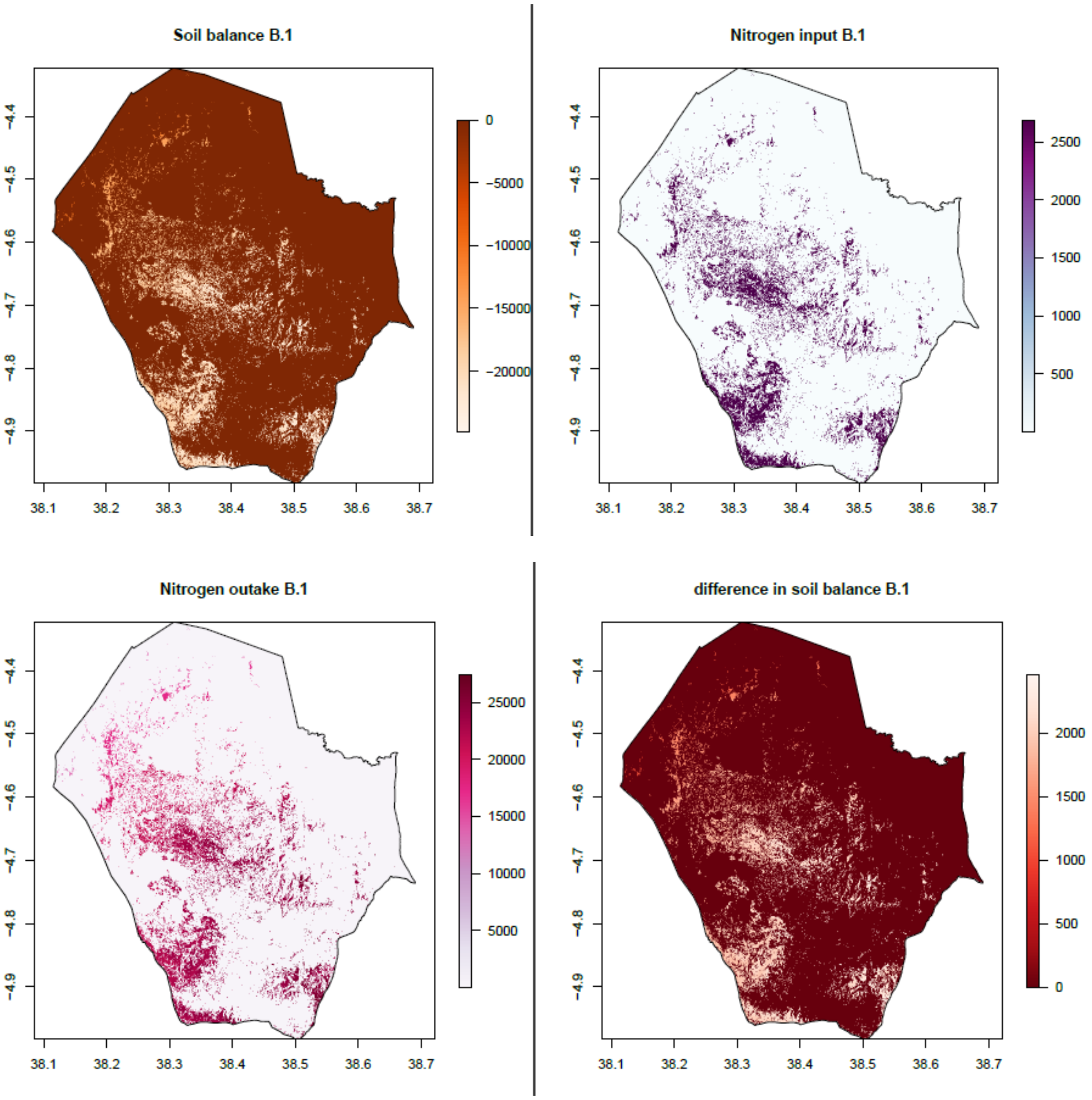


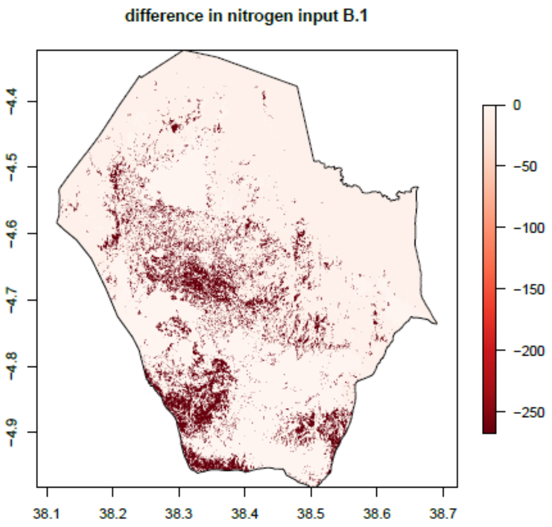
	result	difference	percent	evaluation
CO2 emmissions	112920198	31319377	38.4	high
CO2 from manure	10361020	−2564376	−19.8	medium
CO2 from interic fermetation	102566950	33883752	49.3	high
CO2 per cow	2754	714	35.0	high
CO2 per tonnes of milk	1046	−874	−45.5	high

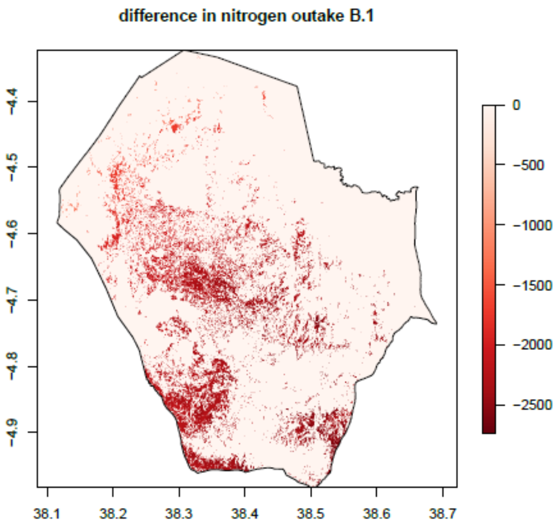
Biodiversity

Same as Farmers group 1

Soil health







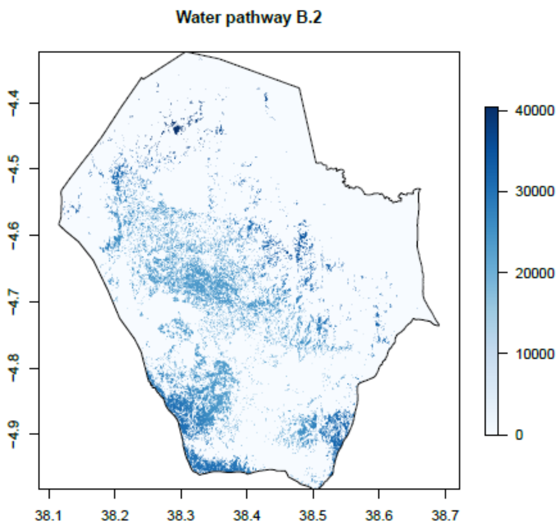
	result	difference	percent	evaluation
nitrogen balance	−6848095770	688808200	−9.1	low
total nitrogen added	923963063	−91841310	−9.0	low
total manure produced	43070000	8395000	24.2	low

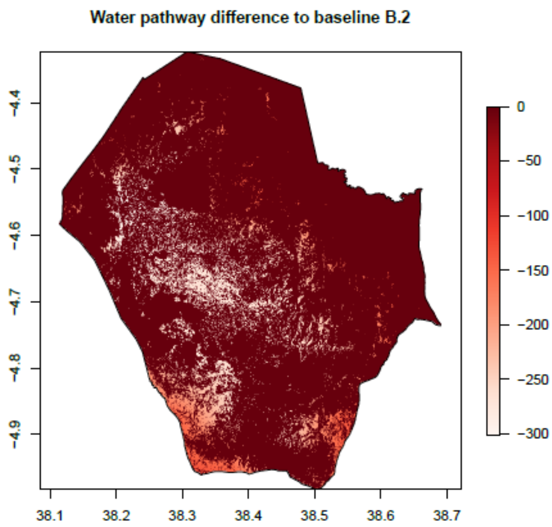
6.4.3 Group: second scenario (B.2)

Productivity

	result	diff	percent	evaluation
milk produced	108000.0	65500.0	154.1	high
tons of maize produced	702.0	−844.0	−54.6	high
total area available for crop	309.0	0.0	0.0	low
total area available for pasture	1395.0	0.0	0.0	low
crop area used	214.5	−85.3	−28.5	medium
pasture area used	236.8	−415.1	−63.7	high
import crop	0.0	0.0	0.0	low
import pasture	0.0	0.0	0.0	low
total numbers of cows	41000.0	1000.0	2.5	low
local breed cow	5000.0	−20000.0	−80.0	high
cross−breed cows	15000.0	0.0	0.0	low
pure breed cows	21000.0	21000.0	Inf	high

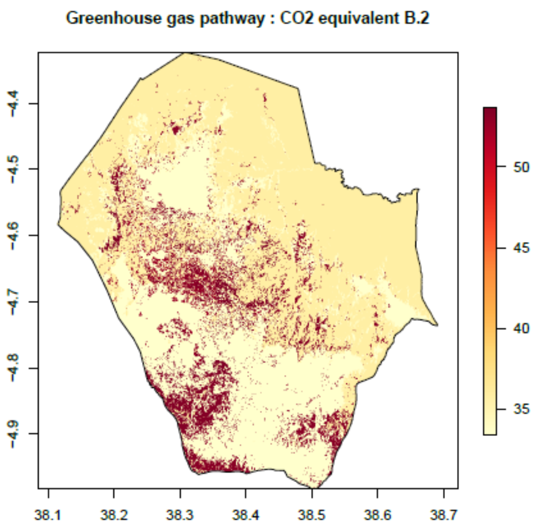
Water impact

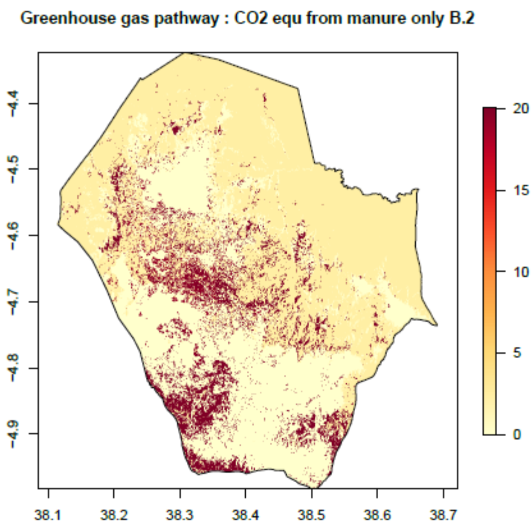


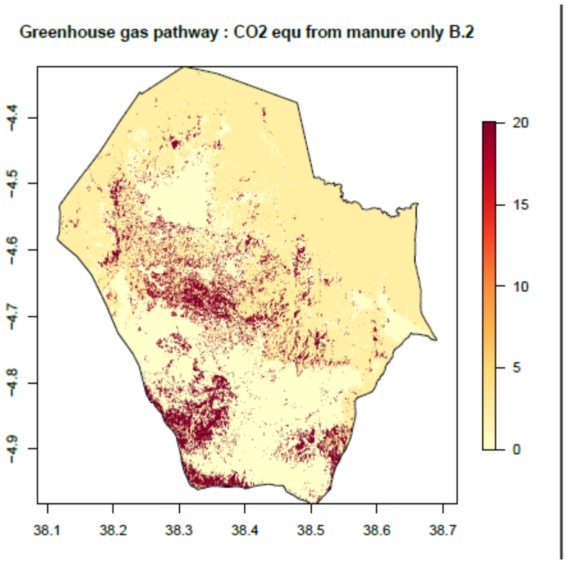


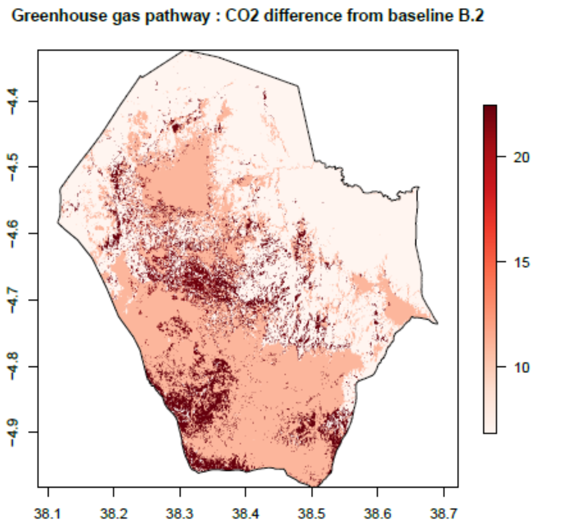
	result	difference	percent	evaluation
total water consumption	1.118973e+11	−9.646658e+10	−46.3	high
water consumption rainfall ratio	3.093000e+01	−2.666000e+01	−46.3	high
water consumption per cow	2.729202e+06	−2.479895e+06	−47.6	high
water consumption per ton of milk	1.036086e+06	−3.866593e+06	−78.9	high
ıverage water consumption intensity	3.032600e+01	−2.619400e+01	−46.3	high

Greenhouse gas emission



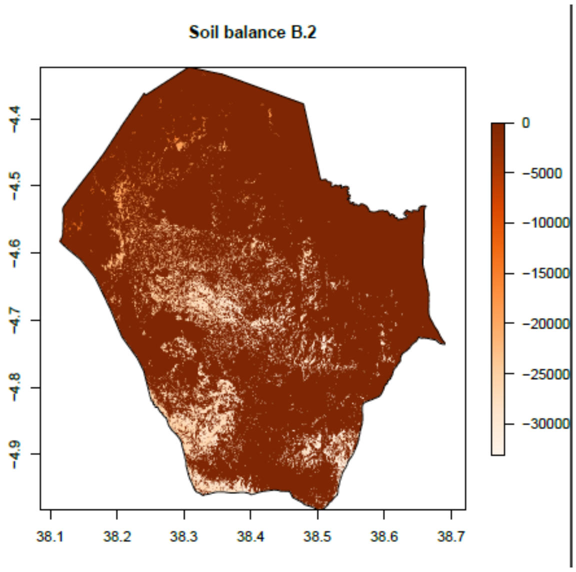


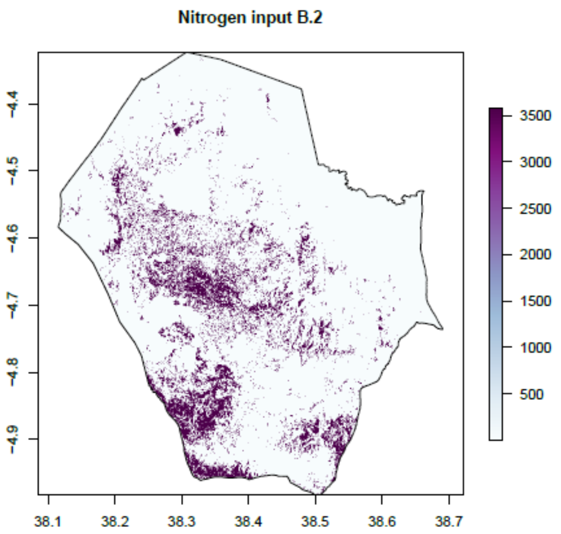




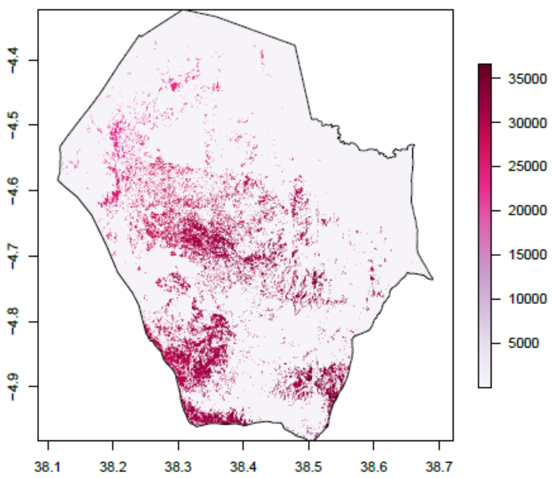
	result	difference	percent	evaluation
CO2 emmissions	112920198	31319377	38.4	high
CO2 from manure	10361020	−2564376	−19.8	medium
CO2 from interic fermetation	102566950	33883752	49.3	high
CO2 per cow	2754	714	35.0	high
CO2 per tonnes of milk	1046	−874	−45.5	high

Soil health

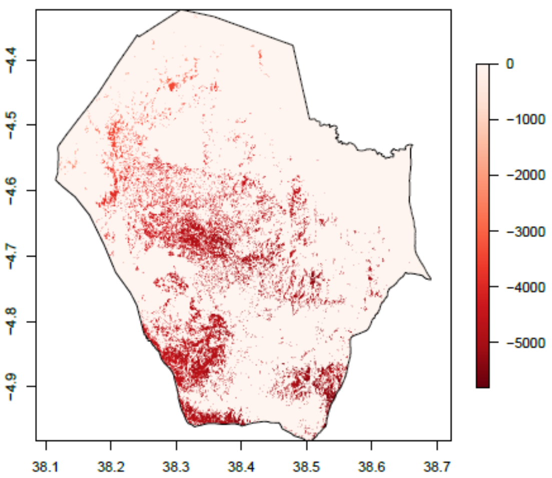




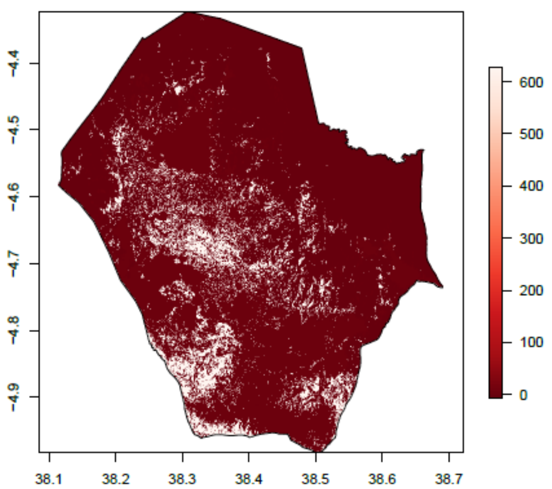
Nitrogen outake B.2



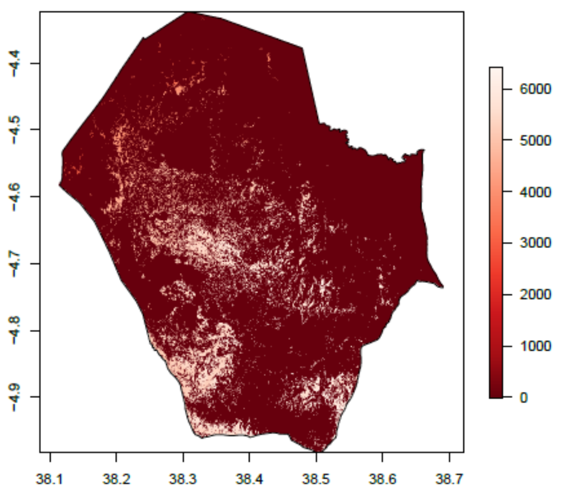
difference in soil balance B.2



difference in nitrogen input B.2



difference in nitrogen outake B.2



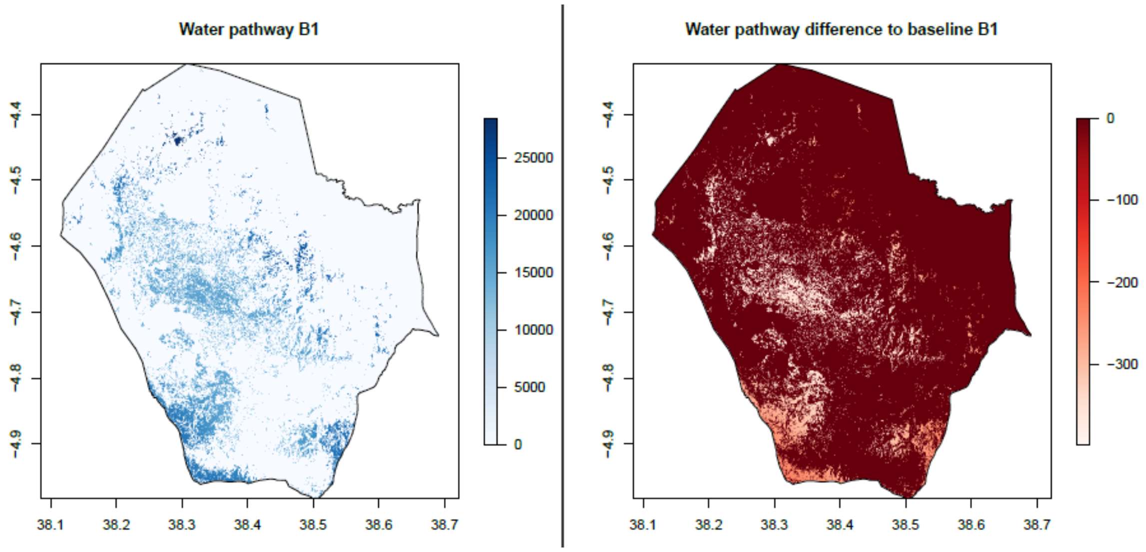
	result	difference	percent	evaluation
nitrogen balance	−9127301417	−1590397447	21.1	low
total nitrogen added	1231959849	216155476	21.3	low
total manure produced	43070000	8395000	24.2	low

6.4.4 Group B: first scenario (Run 1)

Productivity

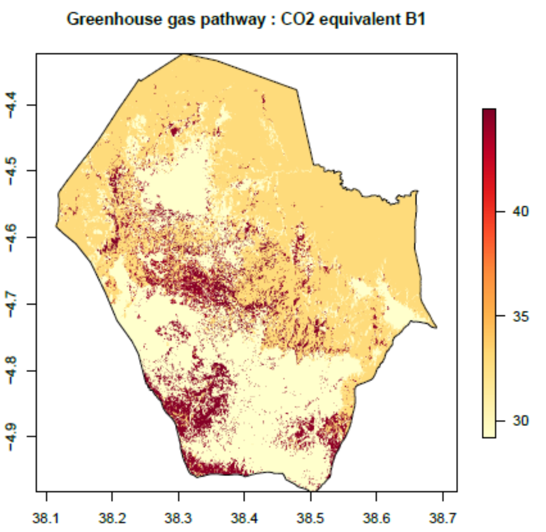
	result	diff	percent	evaluation
milk produced	94500.0	52000.0	122.4	high
tons of maize produced	497.0	−1049.0	−67.9	high
total area available for crop	309.0	0.0	0.0	low
total area available for pasture	1395.0	0.0	0.0	low
crop area used	150.8	−149.0	−49.7	high
pasture area used	265.1	−386.8	−59.3	high
import crop	0.0	0.0	0.0	low
import pasture	0.0	0.0	0.0	low
total numbers of cows	35000.0	−5000.0	−12.5	low
local breed cow	10000.0	−15000.0	−60.0	medium
cross−breed cows	8000.0	−7000.0	−46.7	medium
pure breed cows	17000.0	17000.0	Inf	high

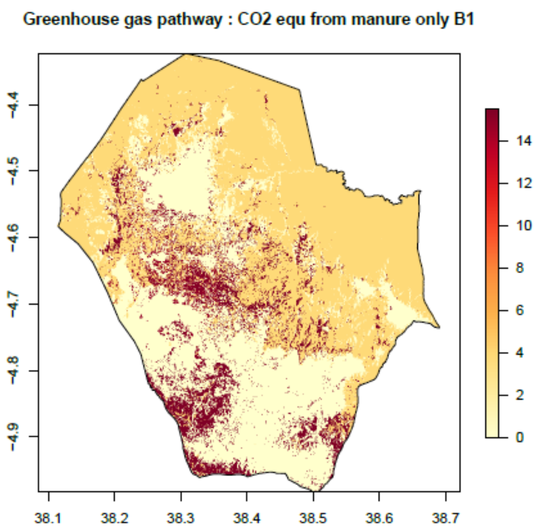
Water impact

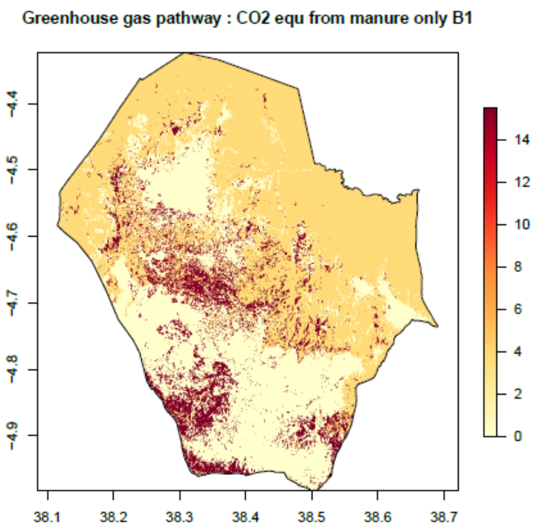


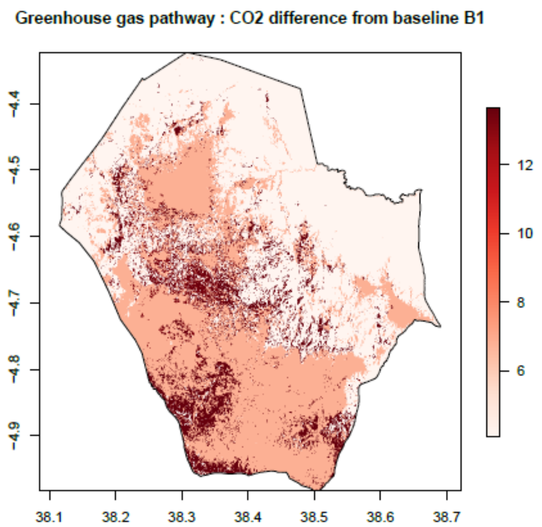
	result	difference	percent	evaluation
total water consumption	7.416484e+10	−1.341990e+11	−64.4	high
water consumption rainfall ratio	2.050000e+01	−3.709000e+01	−64.4	high
water consumption per cow	2.118995e+06	−3.090102e+06	−59.3	high
water consumption per ton of milk	7.848130e+05	−4.117866e+06	−84.0	high
ıverage water consumption intensity	2.010100e+01	−3.641900e+01	−64.4	high

Greenhouse gas emission



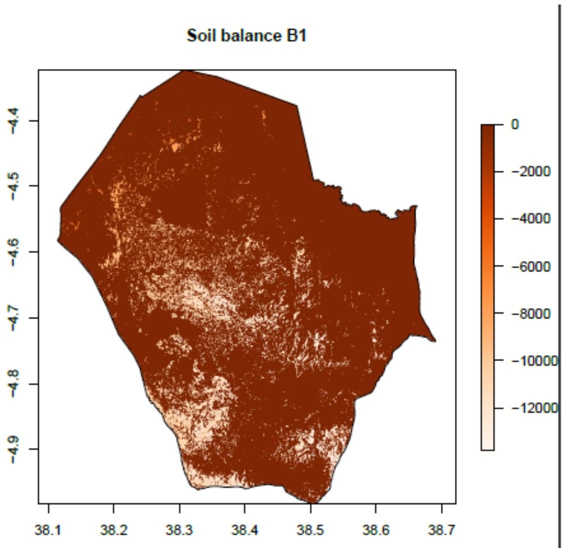


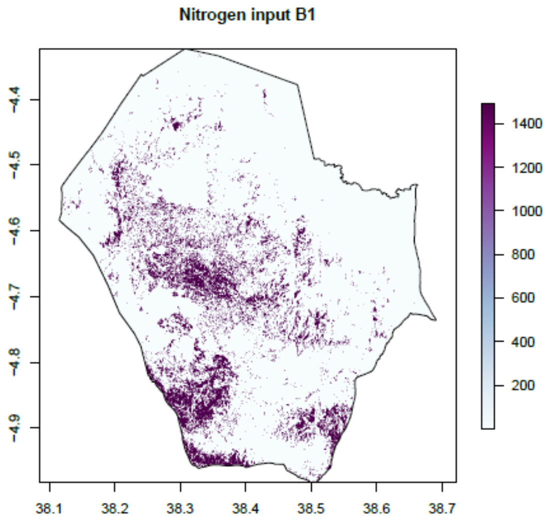


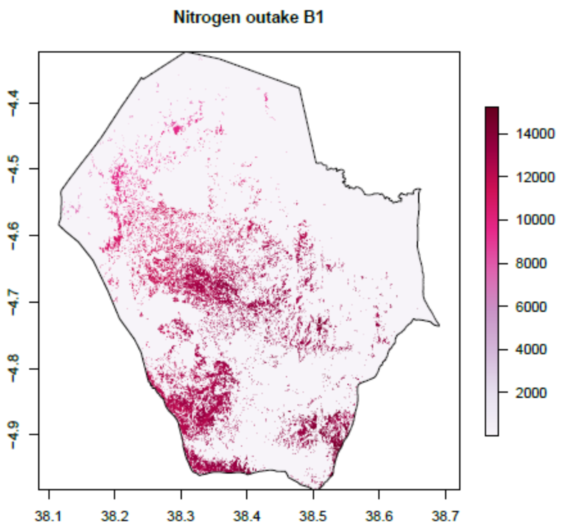


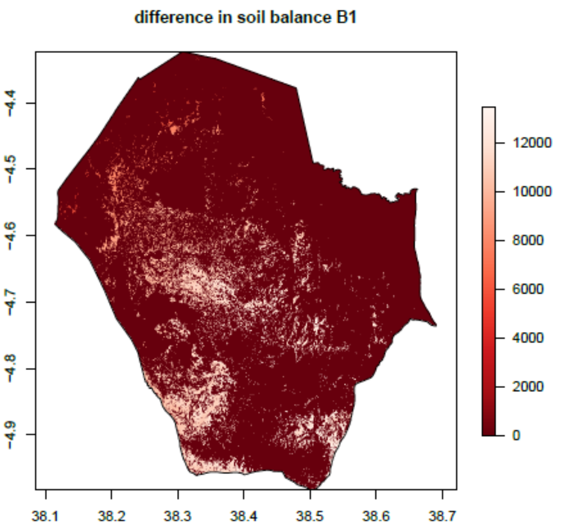
	result	difference	percent	evaluation
CO2 emmissions	100615811	19014990	23.3	medium
CO2 from manure	11034683	−1890713	−14.6	low
CO2 from interic fermetation	89588901	20905703	30.4	medium
CO2 per cow	2875	835	40.9	high
CO2 per tonnes of milk	1065	−855	−44.5	high

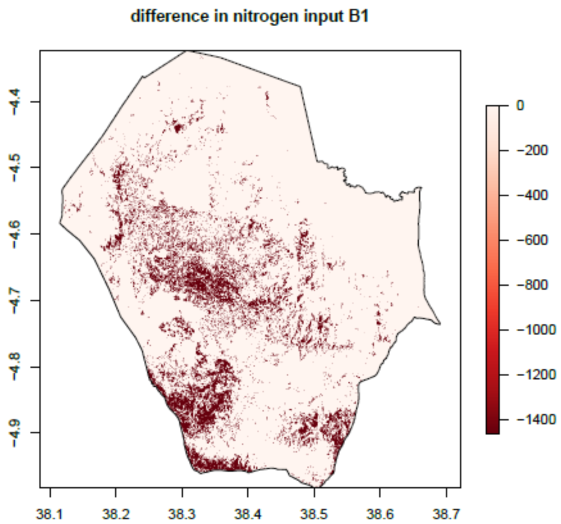
Soil health

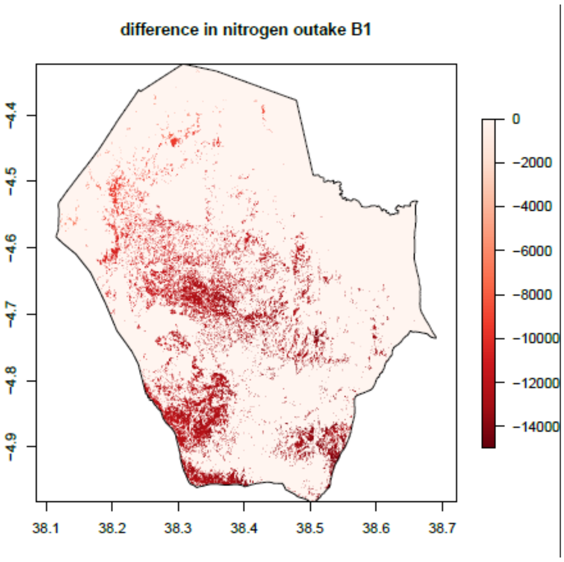

Soil balance B1
−4.4
−4.5
−4.6
−4.7
−4.8
−4.9
38.1 38.2 38.3 38.4 38.5 38.6 38.7
0
−2000
−4000
−6000
−8000
−10000
−12000


Nitrogen input B1
−4.4
−4.5
−4.6
−4.7
−4.8
−4.9
38.1 38.2 38.3 38.4 38.5 38.6 38.7
1400
1200
1000
800
600
400
200


Nitrogen outake B1
−4.4
−4.5
−4.6
−4.7
−4.8
−4.9
38.1 38.2 38.3 38.4 38.5 38.6 38.7
14000
12000
10000
8000
6000
4000
2000


difference in soil balance B1
−4.4
−4.5
−4.6
−4.7
−4.8
−4.9
38.1 38.2 38.3 38.4 38.5 38.6 38.7
12000
10000
8000
6000
4000
2000
0


difference in nitrogen input B1
−4.4
−4.5
−4.6
−4.7
−4.8
−4.9
38.1 38.2 38.3 38.4 38.5 38.6 38.7
0
−200
−400
−600
−800
−1000
−1200
−1400


difference in nitrogen outake B1
−4.4
−4.5
−4.6
−4.7
−4.8
−4.9
38.1 38.2 38.3 38.4 38.5 38.6 38.7
0
−2000
−4000
−6000
−8000
−10000
−12000
−14000

	result	difference	percent	evaluation
nitrogen balance	−3809211797	3727692173	−49.5	low
total nitrogen added	513220222	−502584151	−49.5	low
total manure produced	34675000	0	0.0	low

6.4.5 Group B: second scenario (Run 2)

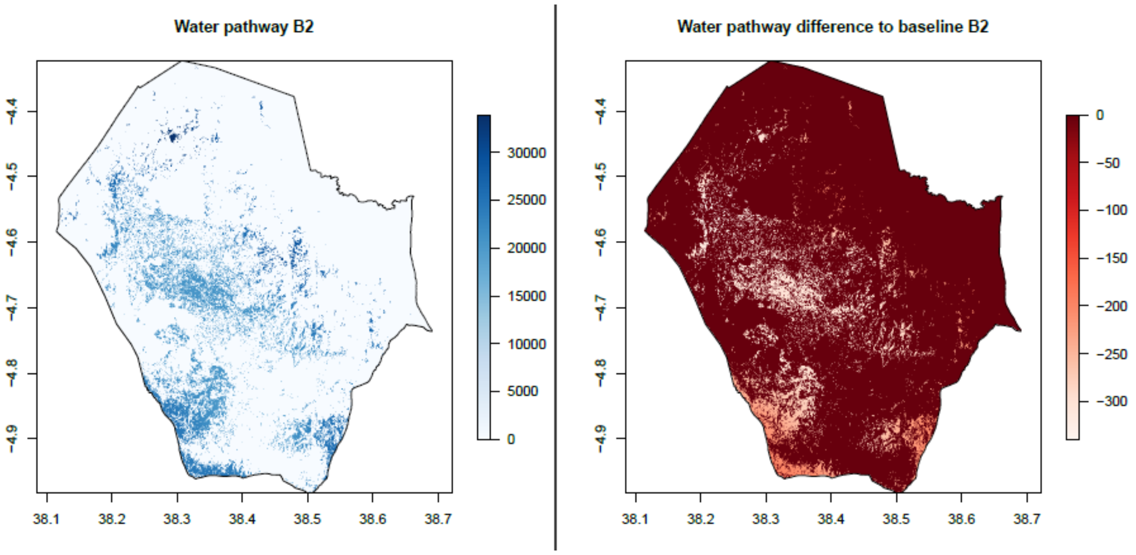
Productivity

	result	diff	percent	evaluation
milk produced	87500.0	45000.0	105.9	high
tons of maize produced	614.0	−932.0	−60.3	high
total area available for crop	309.0	0.0	0.0	low
total area available for pasture	1395.0	0.0	0.0	low
crop area used	174.0	−125.8	−42.0	high
pasture area used	313.2	−338.7	−52.0	high
import crop	0.0	0.0	0.0	low
import pasture	0.0	0.0	0.0	low
total numbers of cows	35000.0	−5000.0	−12.5	low
local breed cow	10000.0	−15000.0	−60.0	medium
cross−breed cows	15000.0	0.0	0.0	low
pure breed cows	10000.0	10000.0	Inf	high

With crop productivity +20%:

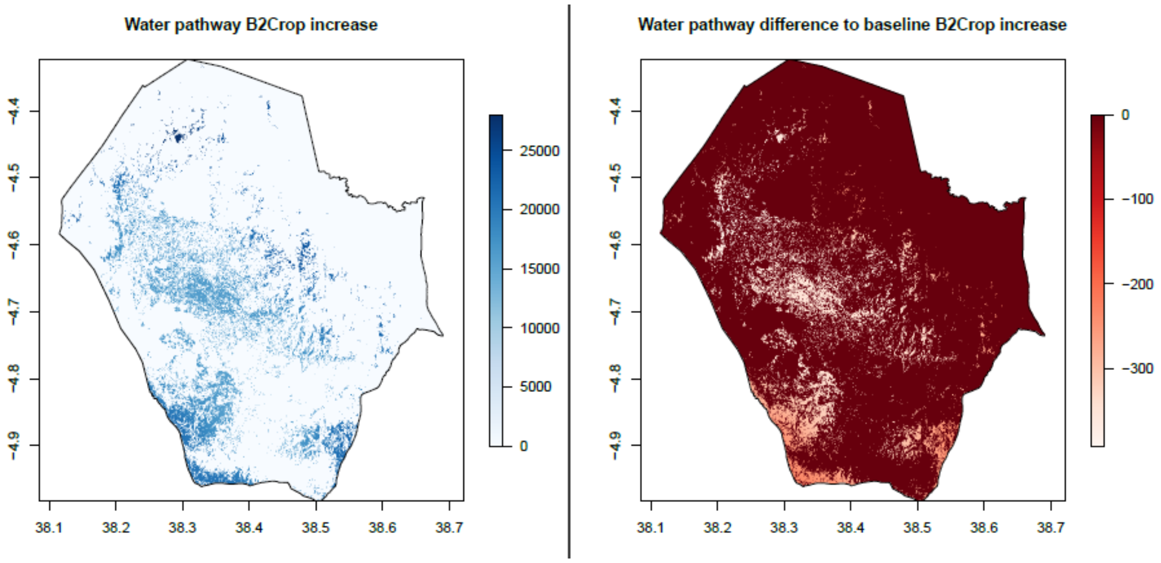
	result	diff	percent	evaluation
milk produced	87500.0	45000.0	105.9	high
tons of maize produced	615.0	−931.0	−60.2	high
total area available for crop	309.0	0.0	0.0	low
total area available for pasture	1395.0	0.0	0.0	low
crop area used	147.7	−152.1	−50.7	high
pasture area used	313.2	−338.7	−52.0	high
import crop	0.0	0.0	0.0	low
import pasture	0.0	0.0	0.0	low
total numbers of cows	35000.0	−5000.0	−12.5	low
local breed cow	10000.0	−15000.0	−60.0	medium
cross−breed cows	15000.0	0.0	0.0	low
pure breed cows	10000.0	10000.0	Inf	high

Water impact



	result	difference	percent	evaluation
total water consumption	9.416906e+10	−1.141948e+11	−54.8	high
water consumption rainfall ratio	2.603000e+01	−3.156000e+01	−54.8	high
water consumption per cow	2.690545e+06	−2.518552e+06	−48.3	high
water consumption per ton of milk	1.076218e+06	−3.826461e+06	−78.0	high
ıverage water consumption intensity	2.552800e+01	−3.099200e+01	−54.8	high

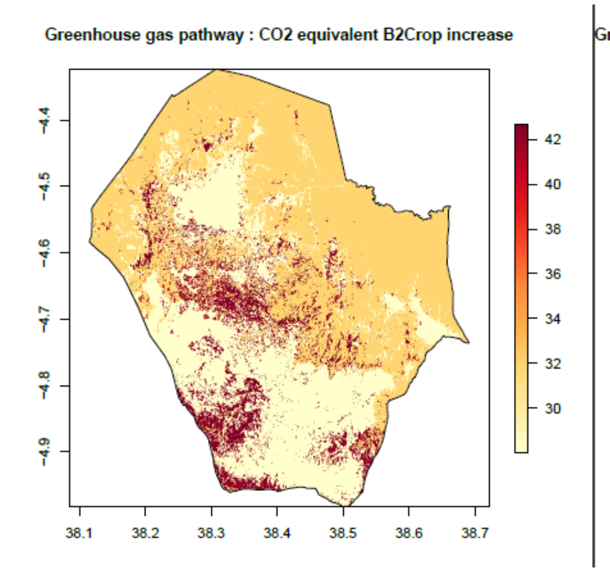
With crop productivity +20%:

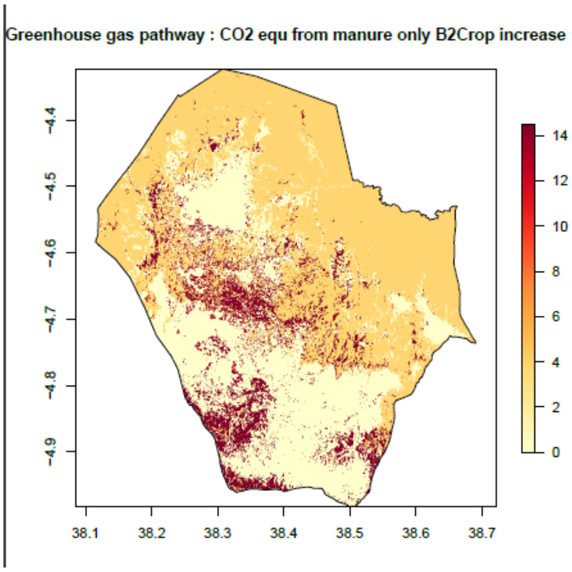


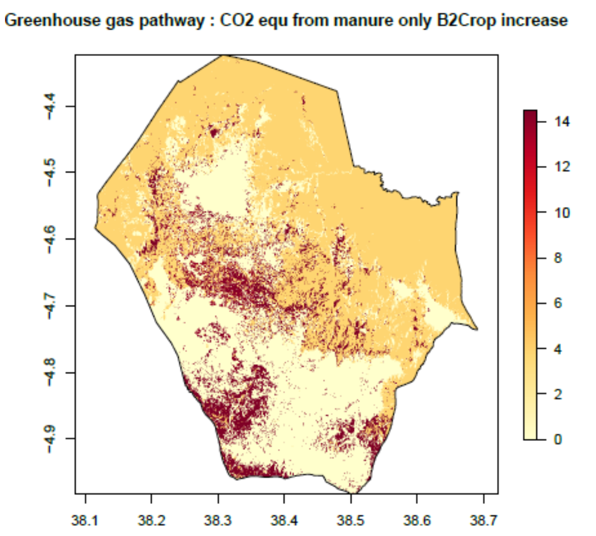
	result	difference	percent	evaluation
total water consumption	7.553819e+10	−1.328257e+11	−63.7	high
water consumption rainfall ratio	2.088000e+01	−3.671000e+01	−63.7	high
water consumption per cow	2.158234e+06	−3.050863e+06	−58.6	high
water consumption per ton of milk	8.632940e+05	−4.039385e+06	−82.4	high
ıverage water consumption intensity	2.047400e+01	−3.604600e+01	−63.8	high

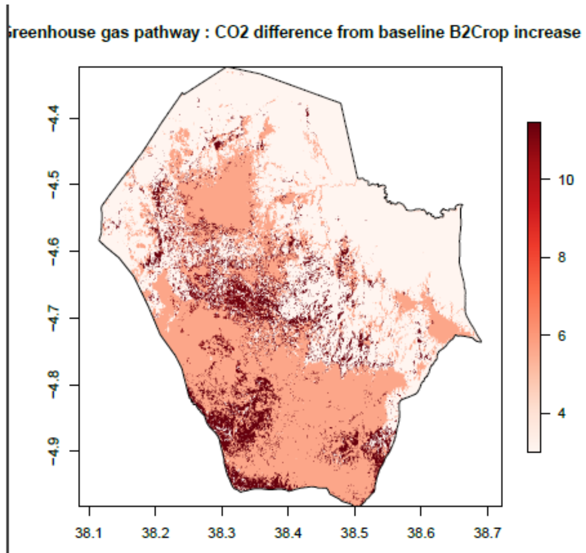
Greenhouse gas emission

With crop productivity +20%:



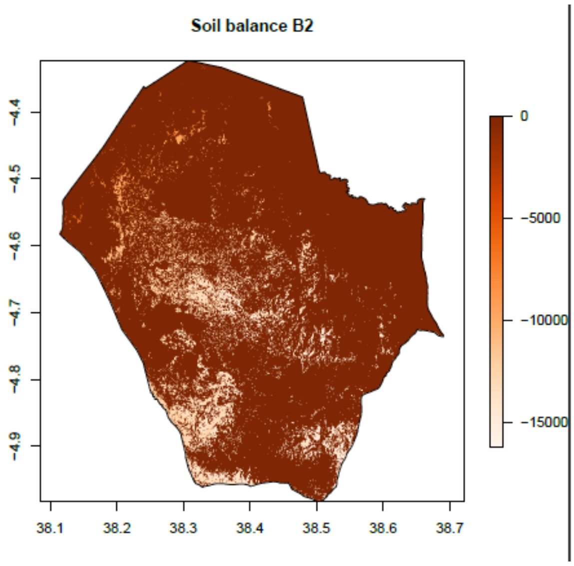


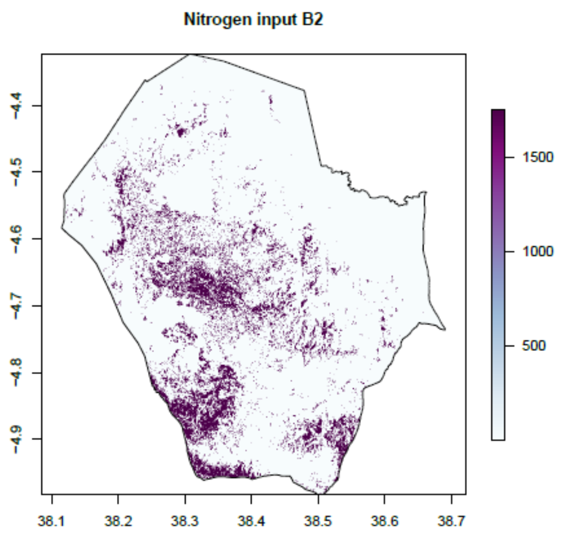


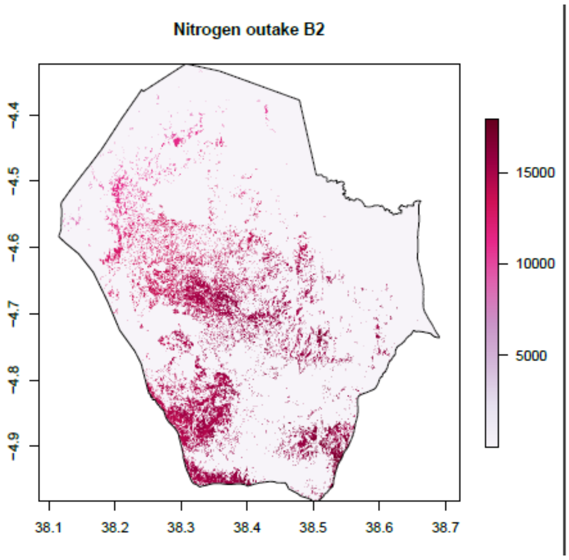


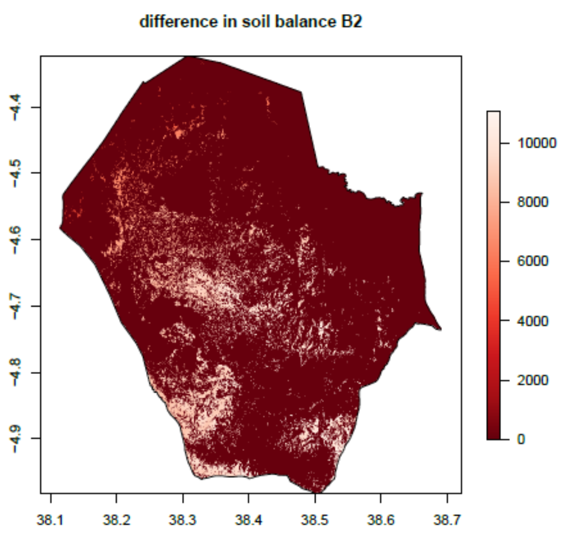
	result	difference	percent	evaluation
CO2 emmissions	96790434	15189613	18.6	medium
CO2 from manure	10846127	−2079269	−16.1	low
CO2 from interic fermetation	85952080	17268882	25.1	medium
CO2 per cow	2765	725	35.5	high
CO2 per tonnes of milk	1106	−814	−42.4	high

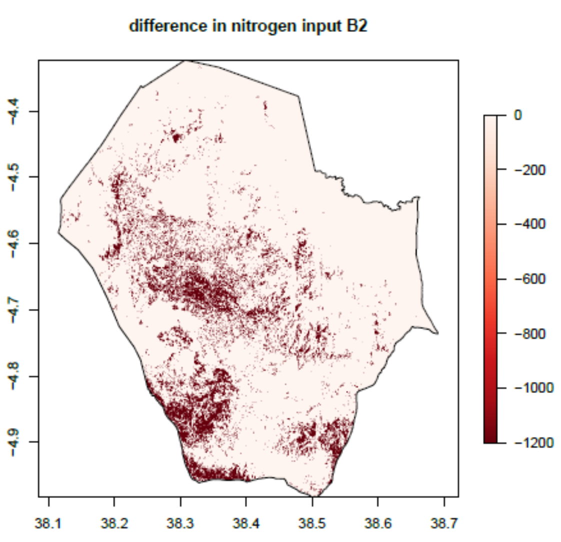
Soil health

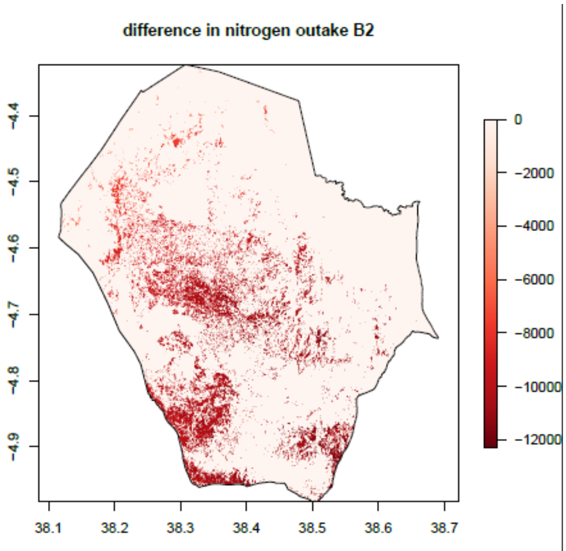

Soil balance B2
0
−5000
−10000
−15000


Nitrogen input B2
1500
1000
500


Nitrogen outake B2
15000
10000
5000

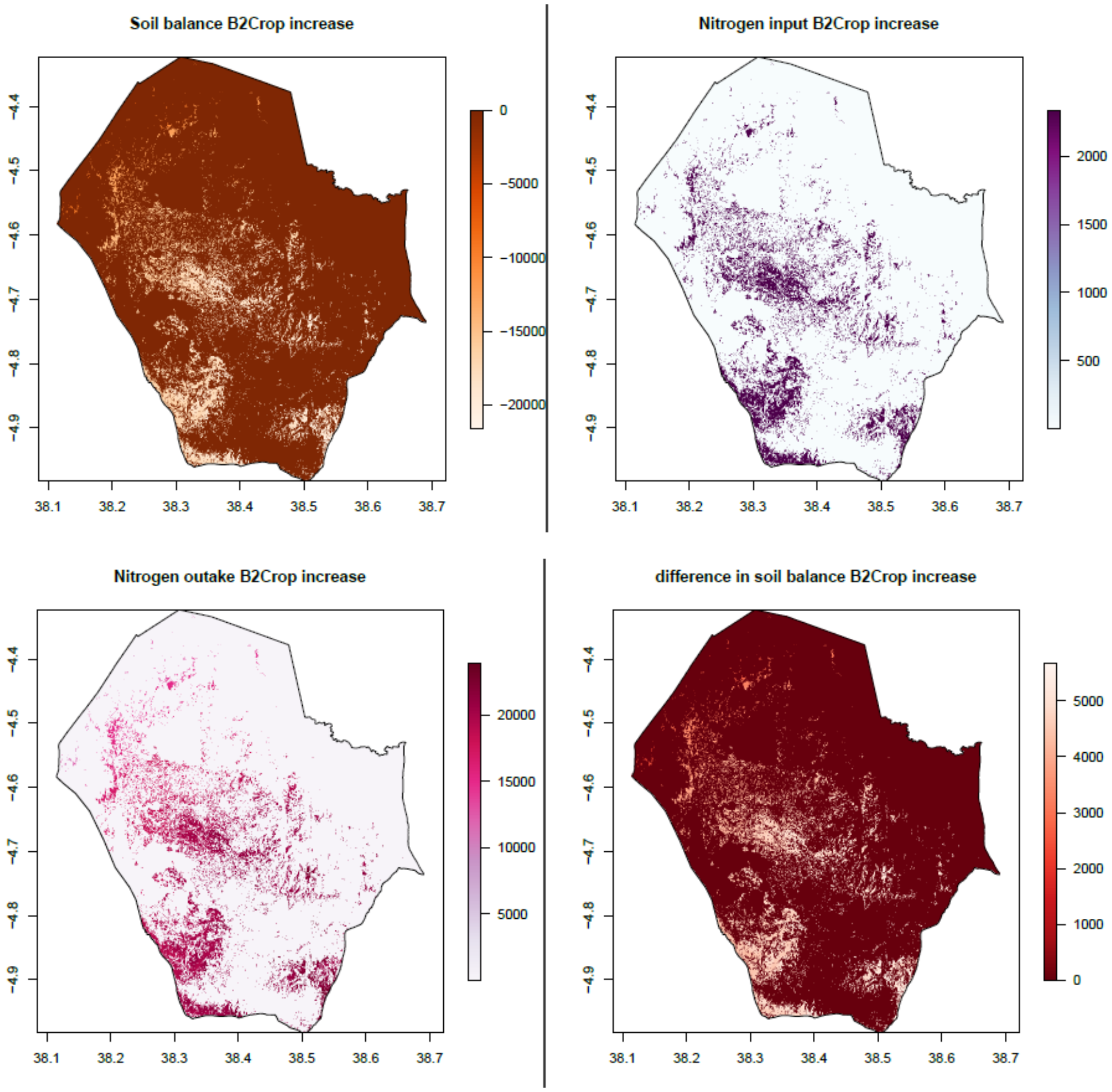

difference in soil balance B2
10000
8000
6000
4000
2000
0

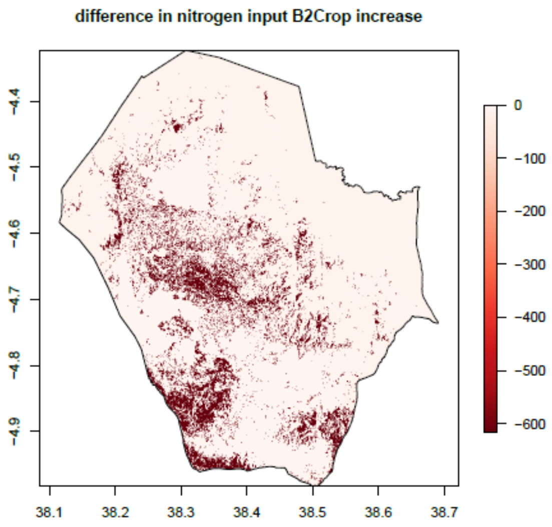

difference in nitrogen input B2
0
−200
−400
−600
−800
−1000
−1200

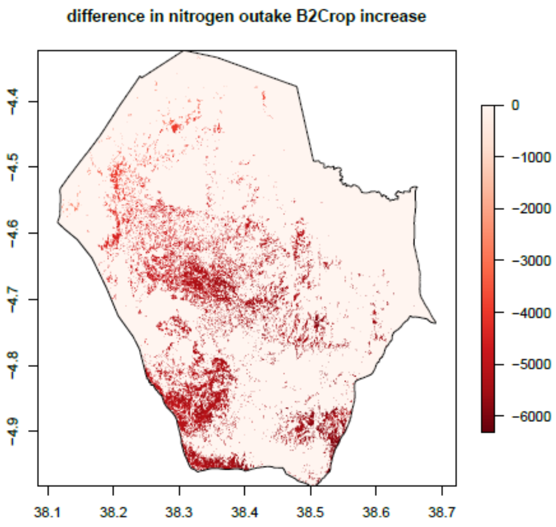

difference in nitrogen outake B2
0
−2000
−4000
−6000
−8000
−10000
−12000

	result	difference	percent	evaluation
nitrogen balance	−4474870859	3062033111	−40.6	low
total nitrogen added	603030215	−412774158	−40.6	low
total manure produced	34675000	0	0.0	low

With crop productivity +20%:







	result	difference	percent	evaluation
nitrogen balance	−5962437865	1574466105	−20.9	low
total nitrogen added	804049377	−211754996	−20.8	low
total manure produced	34675000	0	0.0	low