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Guideline for emission data collection with the TIPI-CAL

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1 Overview

This document explains and facilitates the data collection and data input for greenhouse gas emission calculation with the TIPI-CAL model used in the *agri benchmark* network. To calculate greenhouse gas emissions, we need different data than those usually used and managed by agricultural economists. To aim at an accurate GHG calculation of beef production, all sources of emissions with their related data are captured in the new part of the questionnaire.

This paper aims at simplifying and explaining the use of this new part in the TIPI-CAL questionnaire by economists which have so far not worked intensively with farm-level greenhouse gas emission calculation.

The document begins with a graphical summary of the emission data collection and calculation using the TIPI-CAL in Chapter 2. It outlines the key features of the tool. The following Chapter 3, describes all data points and gives instructions about how these data are collected in the Q- and INP-sheet. It follows the structure of the questionnaire and explains the relevant reasons for data requirements. In Chapter 4, you will find an exemplary overview of data sources that may help you with the preparation of focus group discussions or farm visits. Additionally, this section includes a data collection scheme that might be helpful to gather all necessary data in order to simulate the effects of mitigation strategies on the typical farm's performance and economics.

As the questionnaire and the INP section for emissions, this document is written in English.

1.1 Überblick

Dieses Dokument soll die Datenerhebung und –eingabe für die Emissionsberechnung mit dem in *agri benchmark* Netzwerk genutzten TIPI-CAL Modell erklären und vereinfachen. Für die Berechnung der Treibhausgasemissionen werden andersartige Daten benötigt, als beispielsweise für die betriebswirtschaftliche Analyse. Um die Emissionen der typischen Betriebe möglichst akkurat darzustellen, werden alle relevanten Treibhausgasquellen in dieser Erweiterung des Fragebogens abgedeckt.

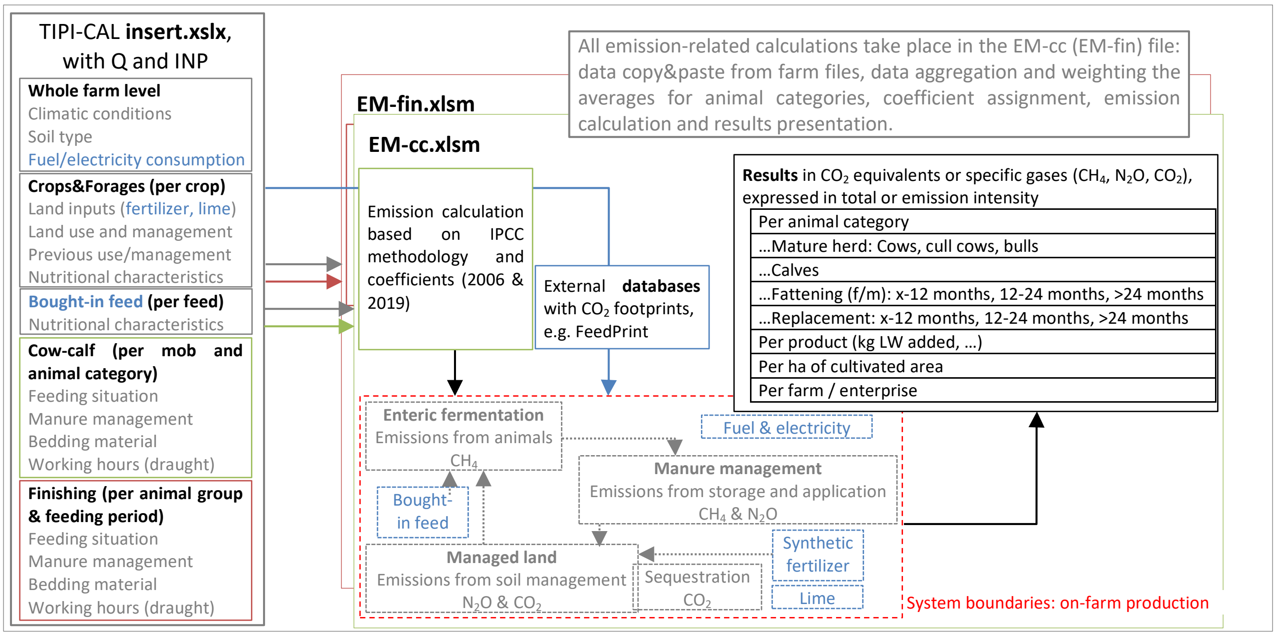
Um die Handhabung dieses Fragbogenteils deshalb auch für Ökonomen zu vereinfachen, die sich nicht intensiv mit der betrieblichen Berechnung von Treibhausgasen auseinander gesetzt haben, geht dieses Dokument auf alle im Fragebogen abgedeckten Emissionsquellen und die dafür erforderlichen Daten ein.

Zu Beginn dieses Dokuments wird in Kapitel 2 die Datenerhebung und Berechnung mit dem TIPI-CAL grafisch dargestellt. Dabei werden die Schlüsseleigenschaften herausgestellt. Im folgenden Kapitel 3 werden alle neuen Datenpunkte beschrieben und erklärt wie sie im Q- und INP-Blatt erhoben werden. Das Dokument folgt dabei in seiner Struktur dem Fragebogen und geht auf die relevanten Erhebungsgründe ein. Zum Schluss gibt dieses Dokument in Kapitel 4 einen beispielhaften Überblick über Datenquellen um in der Vorbereitung der Fokusgruppen oder Betriebsbesuche Hilfestellung zu benötigten Information zu geben. Darüber hinaus enthält der letzte Abschnitt ein Schema zur Erfassung von notwendigen Daten für die Simulation der Effekte von Minderungsmaßnahen auf die Performance und Ökonomie des typischen Betriebs.

Wie auch der Emissions-Abschnitt im Fragenbogen und INP, ist auch dieses Dokument in Englisch verfasst.

2 Summary

Figure 1: Inputs, outputs, and coverage of emission calculation with the TIPI-CAL



Source: the author.

Key features:

- **The emission tool covers all beef-related on-farm production processes and adds relevant off-farm sources.** Besides animal-related emissions, manure and land management are integrated into the calculation. Carbon stocks and changes are estimated for managed soils and (forest) vegetation. With the integration of bought-in feed, fertilizer, soil corrective, fuel and electricity, the tool additionally accounts for relevant off-farm emission sources.
- **Data collection following the scheme of the TIPI-CAL allows a very detailed description of emission sources.** On-farm consumption of fuel and electricity is collected on the whole-farm level; crop and forage production data are collected per crop, feed characteristics are collected per feed and forage; animal production data are collected per mob and animal categories for cow-calf production and per animal group and feeding period for beef finishing production.
- **Results are available per animal category and age group, per product, per area and per farm.** The emission intensities and profiles are available per kg of product, per ha cultivated area and per farm. The detailed emission estimation per animal category and age group allows differentiating the emission profiles also per animal groups in the enterprises.
- **The highly detailed data collection and emission calculation allow tracing the specific effect of a wide range of mitigation measures.** The effect of mitigation strategies that reduce emissions only partially, e.g. high energy density in the last month of the finishing period, can be identified. Besides, performance improvements of specific animal groups, e.g. faster growth of replacement animals, are traceable.

3 Emission data points in the TIPI-CAL

The emission data calculated with the TIPI-CAL cover all relevant on-farm emissions, as there is methane (CH_4) from enteric fermentation and manure management systems, nitrous oxide (N_2O) from manure management and forage cultivation and carbon dioxide (CO_2) from soil management, afforestation, land use change, and fuel consumption. Additionally, it gives the possibility to account for the most important up-stream emissions, as there is fuel, purchased animal feed and mineral N fertilizer.

The emission calculation bases on the IPCC methodology, allowing the user to calculate with 2006 or 2019 coefficients and integrates further factors for the up-stream components enumerated above. The actual calculation of emissions is done with the “EM-fin”(for beef finishing) and “EM-cc” (for cow-calf) Excel files. In this document, we will not give detailed information on the application of the formulae and methodology applied following the IPCC guidelines. For further information on this, contact the author.

We will focus on the insert excel file with its sheets “Q” (questionnaire) and “INP” (input sheet), which contain all data entry points. Important to say, that the emission section in the questionnaire is an add-on, relying on crop and animal information recorded in previous parts of the questionnaire. For an overview of the relevant data sections beyond the emission section itself, please refer to Chapter 4.1.

The emission section starts in the line 3500 in the “Q” sheet. In the “INP” sheet, the related section starts in the line 10000.

When filling out the questionnaire and INP, always respect the colour code.

Figure 2: Colour codes in Q and INP

colour codes:	explanatory notes	data entry in Q / INP	Only in Q: obligatory data entry	Formulas within Q / INP sheet. Do not modify!	Only in INP: Link to Q!

Source: Adapted from insert file, TIPI-CAL, agri benchmark Beef & Sheep.

3.1 Feed codes in Q

The section from line 3501 to line 3549 is described in this paragraph.

Feed codes (1, column C) mandatorily need to be assigned to bought-in feed and for own-grown feed, if no information on cropping systems is available. Via the feed code, CO_2 emission equivalents per tonne of feed consumed can be included in the emission profile. These CO_2 emission equivalents are sourced from the FeedPrint-database (VELLINGA et al., 2013) used in the tool version FeedPrint 2015.03. The tool is available for download (http://webapplicaties.wur.nl/software/feedprintNL/index.asp). The complete list of feed components is too long to be included as a table in this document. It can be found in the "EM-fin" and "EM-cc" Excel files, sheet "feed". Please request support from the author or the *agri benchmark* Beef & Sheep headquarter team. Specific regional feedstuffs with their respective CO_2 emission equivalents can be added to the feed list if they are supplied including the proper literature source.

Digestibility codes (2, column D) classify the feed components regarding their digestibility into "roughage", "silage" and "energy feed". As the following feed characteristics, this information is necessary to estimate the energy available to the animal with the feed ration and the total digestibility of the feed ratio.

The **dry matter fraction** in the percentage of fresh matter (3, column E) can be taken from sections 2.2 (column D) and 2.5 (column C). If it has not been recorded in the crop section of the questionnaire, add it in the emission section.

Other feed characteristics (4-7, columns F-I) rely on test results, either from farm individual test, from regional advice services or national feed nutritional tables. The website https://www.feedipedia.org/ (INRA et al., 2012-2019) offers a repository of various forage and feed if regional feed analysis is not available. In detail, **metabolisable energy** (ME) in MJ/kg DM determines the energy available to the animal. It is mandatory to correctly derive the enteric fermentation emissions. The protein share in the feed ration, collected as **crude protein**, determines the N excreted and is a basis for the N_2O emissions from manure management. The digestibility of each feed component will be used to cross-check the average digestibility of each feed ratio calculated with the tool.

3.2 Climate and whole-farm data in Q

The section from line 3550 to line 3584 is described in this paragraph.

Climate data is needed to correctly calculate the emission from manure management systems. Additionally, energy requirements of animals increase – and with them the potential CH_4 emissions from enteric fermentation – if animals have to cope with low temperatures for a significant time of the year. Average seasonal temperatures and their fluctuations are available from weather stations or climate websites. All data are required in Celsius.

The amount of (fossil) energy use can differ significantly between different beef production systems. To integrate this parameter in the comparison, we need to add the quantity of **fuel** (in litre) and **electricity** (in kWh) consumed annually on the farm.

Given the high variety of manure management systems and the high variability of codes (detailed description in the "Animal management section"), a **description of the manure management** helps to check and assign the correct code. As manure can serve for several purposes, such as heating material or construction components besides the "common" fertilisation purpose, the specification of **manure use** in the share of total manure available is necessary to assign the right quantity of manure applied on soils. The sum of all manure use purposes needs to sum up to 1.

In IPCC 2006 guideline, the **weight of a mature cow in average condition** was used as a reference weight for potential weight gains and related required energy intake to estimate enteric emissions. In the IPCC refinements published in 2019, this section has been specified as the target weight of each animal category. We collect this information in the cow-calf (weight of cull/slaughter animals and weaned calves) and beef finishing enterprise sections (final weight per animal group). It is not mandatory to fill in any information here.

3.3 Animal management in Q

The section from line 3585 to line 3694 is described in this paragraph. It adds necessary animal management parameters to the information collected in the CC and FIN enterprise sections in order to estimate the energy requirements affecting the enteric emissions. Additionally, it covers all relevant information about manure management related emissions.

This section is split into the two subsections "COW-CALF" and "FINISHING". This subdivision follows the structure of the enterprise sections, where we collect the data as the share of total days per year per animal category in the cow-calf section, whereas in the finishing section, we collect the data per animal group and feeding period. The following paragraphs 3.3.13.3.1 and 3.3.2 describe how to apply this structure to the emission information.

The code-lists applied to this questionnaire section refer to the IPCC guidelines 2006 and their refinements from 2019. The **feeding situation** describes the effort of animals to search their feed.

Table 1: Feeding situation according to IPCC guidelines

Classification	Description	Code number (relevant for FIN)
Confined/stall	animals are confined to a small area (tethered, pen, barn) with the results that they expend very little or no energy to acquire feed	1
Pasture	animals are confined in areas with sufficient forage requiring modest energy expense to acquire feed	2
Grazing large areas	animals graze in open rangeland or hilly terrain and expend significant energy to acquire feed	3

Source: Adapted from IPCC, 2006.

The **manure management systems** vary in type and length of storage. It is important to select them carefully as the related emission coefficients might differ significantly. The description of manure storage and application in the section “Climate and whole-farm data” might help to verify the selection made by interviewers.

Table 2: Manure management systems according to IPCC guidelines

Classification	**Description**	**Code number**
Pasture / Range / Paddock	The manure from pasture and range grazing animals is allowed to lie as deposited and is not managed.	1
Daily spread	Manure is routinely removed from a confinement facility and is applied to cropland or pasture within 24 hours of excretion.	2
Solid storage	The storage of manure, typically for a period of several months, in unconfined piles or stacks. Manure is able to be stacked due to the presence of a sufficient amount of bedding material or loss of moisture by evaporation. Solid stores can be covered or compacted. In some cases, bulking agents or additives are added.	3
Solid storage - covered	Similar to solid storage, but the manure pile is a) covered with a plastic sheet to reduce the surface of manure exposed to air and/or b) compacted to increase the density and reduce the free air space within the material.	4
Solid storage - bulking agent addition	Specific materials (bulking agents) are mixed with the manure to provide structural support. This allows the natural aeration of the pile, thus enhancing decomposition. (e.g. sawdust, straw, coffee husks, maize stover).	5
Solid storage - additives	The addition of specific substances to the pile in order to reduce gaseous emissions. Additions of certain compounds such as attapulgite, dicyandiamide or mature compost have shown to reduce N_2O emissions; while phosphogypsum reduces CH_4 emissions.	6
Dry lot	A paved or unpaved open confinement area without any significant vegetative cover. Dry lots do not require the addition of bedding to control moisture. Manure may be removed periodically and spread on fields.	7
Liquid / Slurry - 1 month, no cover	Manure is stored as excreted or with some minimal addition of water or bedding material	8

Liquid / Slurry - 3 months, no cover	in tanks or ponds outside the animal housing. Manure is removed and spread on fields once or more in a calendar year. Manure is agitated before removal from the tank/ponds to ensure that most of the VS are removed from the tank. Covers on manure management systems can impact emissions of direct N_2O, CH_4 and NH_3. With N_2O and CH_4 emission, the effect of the cover depends upon the character of the cover material.	9
Liquid / Slurry - 4 months, no cover		10
Liquid / Slurry - 6 months, no cover		11
Liquid / Slurry - 12 months, no cover		12
Liquid / Slurry - 1 month, with cover		13
Liquid / Slurry - 3 months, with cover		14
Liquid / Slurry - 4 months, with cover		15
Liquid / Slurry - 6 months, with cover		16
Liquid / Slurry - 12 months, with cover		17
Liquid / Slurry - 1 month, natural cover		18
Liquid / Slurry - 3 months, natural cover		19
Liquid / Slurry - 4 months, natural cover		20
Liquid / Slurry - 6 months, natural cover		21
Liquid / Slurry - 12 months, natural cover		22
Uncovered anaerobic lagoon	A type of liquid storage system designed and operated to combine waste stabilization and storage. Lagoons have a lower depth and a much larger surface compared to liquid slurry stores. Anaerobic lagoons are designed with varying lengths of storage (up to a year or greater), depending on the climate region, the volatile solids loading rate, and other operational factors. The supernatant water from the lagoon may be recycled as flush water or used to irrigate and fertilise fields.	23
Pit storage below animal confinements - 1 month	Collection and storage of manure usually with little or no added water typically below a	24

Pit storage below animal confinements - 3 months	slatted floor in an enclosed animal confinement facility, usually for periods less than one year. Manure may be pumped out of the storage to a secondary storage tank multiple times in one year, or stored and applied directly to fields. It is assumed that VS removal rates on tank emptying are >90%.	25
Pit storage below animal confinements - 4 months		26
Pit storage below animal confinements - 6 months		27
Pit storage below animal confinements - 12 months		28
Anaerobic digester - low leakage, gastight storage	Animal manure with and without straw is collected and anaerobically digested in a containment vessel. Co-digestion with other waste or energy crops may occur. Digesters are designed, constructed and operated according to industrial technology standard for waste stabilization by the microbial reduction of complex organic compounds to CO_2 and CH_4. Biogas is captured and used as a fuel. Digestate is stored either in open storage, in covered storage with no leakage control, or in gas-tight storage with gas recovery or flaring.	29
Anaerobic digester - low leakage, low quality gastight storage		30
Anaerobic digester - low leakage, open storage		31
Anaerobic digester - high leakage, gastight storage	Animal manure with and without straw is collected and anaerobically digested in a covered lagoon. Digesters are used for waste stabilization by the microbial reduction of complex organic compounds to CO_2 and CH_4 Biogas is captured and flared or used as a fuel. After anaerobic digestion, digestate is stored either openly, covered, or gas tightly.	32
Anaerobic digester - high leakage, low quality gastight storage		33
Anaerobic digester - high leakage, open storage		34
Burned for fuel	The dung and urine are excreted on fields. The sun-dried dung cakes are burned for fuel.	35
Deep bedding - 1 month, no mixing	As manure accumulates, bedding is continually added to absorb moisture over a production cycle and possibly for as long as 6 to 12 months. This manure management system also is known as a bedded pack manure management system and may be combined with a dry lot or pasture. Manure may undergo periods where animals are present and are actively mixing the manure or periods in which the pack is undisturbed.	36
Deep bedding - <1 month, no mixing		37
Deep bedding - >1 month, active mixing		38
Deep bedding - <1 month, active mixing		39

Composting - in-vessel	Composting, typically in an enclosed channel, with forced aeration and continuous mixing.	40
Composting - static pile	Composting in piles with forced aeration but no mixing, (without) runoff/leaching containment.	41
Composting - intensive windrow	Composting in windrows with regular (at least daily) turning for mixing and aeration, (without) runoff/leaching containment	42
Composting - passive windrow	Composting in windrows with infrequent turning for mixing and aeration, (without) runoff/leaching.	43
Aerobic treatment - natural aeration	The biological oxidation of manure collected as a liquid with either forced or natural aeration. Natural aeration is limited to aerobic and facultative ponds and wetland systems and is due primarily to photosynthesis. Hence, these systems typically become anoxic during periods without sunlight.	44
Aerobic treatment - forced aeration		45

Source: Adapted from IPCC, 2006.

Unlike the previous, **working hours** and **bedding material** are optional information. **Working hours** of draught animals might only be relevant in some developing countries, where animals replace machinery for fieldwork. In these specific cases, it is important to estimate the working hours per animal as it has an impact on the energy requirement and thus the emissions from enteric fermentation. **Bedding material** supplied for animal comfort is only relevant in few confined systems. Where it is added, even if only seasonal, the amount and type of bedding material contributes to the amount of organic material in the manure and has an impact on the emissions from manure management. To correctly estimate this emission impact, specify the type of bedding supplied (referring to the table below), the amount of material supplied per animal and day, and the number of days (per year) the bedding is supplied to animals.

Table 3: Bedding material

Type of bedding material	Code number
Straw	1
Sand	2
Paper	3
Sawdust/wood shavings	4

Source: Adapted from

The **milk yield** is relevant for all cow-calf systems, as it increases the energy required for producing milk (regardless if this milk is sold or consumed within the farm, e.g. for suckling calves).

3.3.1 Cow-calf

As described above, the questionnaire structure reflects the structure of the cow-calf enterprise with its split by animal category and annual values. The possibility of two mobs, i.e., two herds according to calving period, breed, etc. is also reflected in the emission section. Assuming the other animal management components, such as **feeding situation** and **manure management**, correlate to this subdivision, we collect the data on feeding situation and manure management in the same way: per animal category and year. To anticipate an expected variability of feeding situation and manure management system, e.g., due to seasonally differing handling, the questionnaire foresees splitting up the total by the share of days per year. If cows and their calves are kept (and fed) in barns during 4 winter months and spend the rest of the year (8 months) grazing on pastures e.g., we request you to assign 0,33 to “confined” and 0,67 to “pasture” to all animal categories, this applies to (cows, heifers and calves) – and to proceed the same way for manure management. The sum of these shares has to be 1. Regarding manure management, you are required to select and copy the correct manure management system from column K (lines 3601-3645), e.g. “1 = Pasture / Range / Paddock” and paste it into cell A3603 ff.

Further information on **working hours** and **bedding materials** needs to be noted if relevant in the analysed production system. For details, please refer to the information in the previous sub-Chapter 3.3.

Although most of the cow-calf production systems hardly record the **quantity and quality of mother cows’ milk production**, this information is important to fully calculate the animal-related emissions. Milk production during lactation increases the need for feed energy required by mother cows and impacts their emission factor. The protein content of milk is a sink for nitrogen that needs to be deducted from the nitrogen emitted in urine and faeces. Expert knowledge and literature values are good sources to fill these cells (lines 3654-3660).

In case the milk is a considerable product of the production system, e.g. on dual-purpose farms, you are requested to fill in the diary section of the questionnaire, too (lines 691-844).

3.3.2 Finishing

As described above, the questionnaire reflects the structure of the beef finishing enterprise with its split by animal group and feeding period. The questionnaire structure allows assigning **one** specification per feeding period. The feeding periods have been defined in section “4.4 Feeding period and rations” (lines 933-1177) splitting the total duration of the finishing period into time sections differing by feed rations. This reflects common animal management strategies to cope with the seasonality of feed supply or growth adapted feeding. I assume a close correlation of these feeding periods to other animal management components, such as feeding situation, manure management or bedding supply.

However, there might be on-farm situations, where a) these other animal management components do not change although changing feed rations (e.g. although seasonal or growth-related feed supply differs, animals remain in the same feeding situation and manure management system) or b) these other animal management components show higher variability than feed rations (e.g. animals receive the same feed during their entire finishing period, but the manure management differs seasonally). In the case of a), the animal management codes are simply copied over all feeding different periods. In the case of b), we request to split up the feeding periods in section 4.4 according to the higher variability of the other animal management components, e.g. the previous finishing period of 365 days with the same silage based feed ratio is now split into two sections of 122 days and 243 days with the same silage based feed ratio, allowing to differ the manure management strategies of winter-months and the rest of the year.

Further information on **working hours** and **bedding materials** needs to be noted if relevant in the analysed production system. For details, please refer to the information in the previous sub-Chapter 3.3.

3.4 Land management in Q

This paragraph describes the questionnaire section from line 3695 to 3791. It adds all necessary information to the previously collected information in the crop and forage section in order to estimate the N_2O emissions from cultivated and grazed land and CO_2 emissions from land use and land use change. In the following sub-chapters, I differentiate between the current land use and management and previous land use, management and conversion.

Common to the complete land management section is the data collection per (currently) cultivated crop and its total acreage, as noted in the questionnaire's section "2.2 Land use, Yields, Prices and direct payments", column B. If the management of one crop or one pasture shows significant spatial variation on farm level, e.g. partial management of big areas due to difficult groundwater situation, etc. it might be useful to subdivide these crop or pasture areas. In case this is not possible, the majority of an area determines the classification.

The code-lists for **land use**, **land management** and **land input** used in this section are the same for current and previous land use, too. They rely on the IPCC tables for relative stock changes factors of carbon in soils.

Table 4: Land use classification

Classification	Description	Code number
Grassland	Native and/or permanent grassland	1
Crop - long-term cultivated	Continuously management with predominantly annual crop for >50 years	2
Crop - paddy rice	Long-term (>20 years) annual cropping of wetland rice, can include double cropping	3
Crop - perennial crops/trees	Long-term perennial crops such as fruit, nut, coffee, cacao	4
Crop - set aside (< 20 years)	Temporary set-aside of annually cropland, revegetate with perennial grasses	5
Forest (native or managed)	Native or long-term, non-degrade and sustainable managed	6
Shifting cultivation - shortened fallow, forest to cropland	Tropical forest or woodland is cleared for planting of annual crops for a short time (3-5 years) and then abandoned to regrowth	7
Shifting cultivation - mature fallow, forest to cropland		8

Source: Adapted from IPCC, 2006.

Table 5: Land management classification

Classification	Description	Code number
Grassland - nominally managed (non-degraded)	Low or medium intensity grazing regimes, periodic cutting and removal of above ground vegetation, without significant improvements	1
Grassland – high intensity grazing (moderately degraded)	High intensity grazing systems, (or cutting and removal of vegetation) with shifts in vegetation composition and possibly productivity, not severely degraded	2
Grassland - severely degraded	Major long-term loss of productivity and vegetation cover, due to severe mechanical damage to the vegetation and /or severe soil erosion	3
Grassland - improved	Sustainable managed with light to moderate grazing pressure (or cutting and removal of vegetation), receive at least one improvement (e.g. fertilisation, species improvement, irrigation)	4
Crop - full tillage	Full inversion and /or frequent within year tillage operations, little surface (<30%) covered by residues at planting	5
Crop - reduced tillage	Primary and/or secondary tillage with reduced soil disturbance (shallow, without full inversion), surface >30% covered by residues at planting	6
Crop - no tillage	Direct seeding without primary tillage, minimal soil disturbance in seeding zone	7
Forest (native or managed)	-	8

Source: Adapted from IPCC, 2006.

Table 6: Land input classification

Classification	Description	Code number
Grassland - medium (only to improved grassland)	Improved grasslands without additional management inputs	1
Grassland - high (only to improved grassland)	Improved grasslands with one or more additional management inputs (beyond that required to be classified as improved grassland)	2
Crop - low	Low residue return (removal or burn of residues), frequent bare-fallowing, production of crops yielding low residues (vegetables, cotton), no mineral fertilizer or N-fixing crops	3
Crop - medium	Representative for annual cereal cropping with 100% of residues left on field or replaced with organic matter(manure) if removed, with mineral fertilizer or N-fixing crops	4
Crop - high without manure	Significant greater crop residue inputs than “medium” with additional practices, e.g. high residue yielding crops, green manures, cover crops, improved fallows,…	5
Crop - high with manure	Significant greater crop residue inputs than “medium” with additional practices, regular addition of animal manure	6
Forest (native or managed)	-	7

Source: Adapted from IPCC, 2006.

3.4.1 Current land use and management

The current land management (lines 3698 to 3743) can be subdivided into management and inputs. Together with the information on yield (lines 563 to 583, column C), nitrogen input (lines 632 to 652, column C) and calcium input (lines 632 to 652, column F) it enables to estimate the land management related emissions from crop and forage production.

Some **management and inputs** might only be partial to a pasture/crop (e.g. pasture/crop renewal) or not done annually (liming every 5th year). If this is the case, please note it in the grey column and consider this fraction of a total for the yellow cells, e.g. pasture is renewed every 10 years, note 0,1 for that pasture; e.g. one tonne of limestone is applied every 5th year, note 0,2 t/ha annually.

Residues harvested are noted in percentage (note in decimals, e.g. 0,5 for 50 %) of the total area. This is especially relevant to annual crops. It determines the amount of organic matter left on the land and subject to N-mineralization and direct and indirect N_2O emissions. The fraction of **land renewed** is noted the same way as residues harvested. For annual crops, generally of factor of 1 is correct, whereas for perennial grasslands 1/n, with n = average lifetime of pasture (or average annual fraction of pasture renewal). The amount of land renewed determines the amount of above and below ground organic matter subject to N-mineralisation and related N_2O emissions. The acreage of **land burned** per crop, e.g. for residue management, is collected in ha. It reduces the amount of organic matter available for N-mineralization, but adds emissions with burning.

To estimate the fraction of N lost via leaching and the related indirect N_2O emissions, it is important to specify if the land areas are susceptible to **leaching** via a yes=1/no=0 coding. Following the IPCC guideline, leaching is relevant where irrigation (except drip irrigation) is used and in wet climates, where the mean annual rainfall reduced by the evapotranspiration is greater than the soil water holding capacity.

The same coding is used to specify if a land area is **drained organic soils** (yes=1/no=0 coding), which would contribute to the land-management related N_2O emissions and soil carbon loss related CO_2 emissions.

The **land use** and **land management** specifications per pasture/crop following the IPCC classifications are necessary to determine the soil carbon stock and (if land use change is relevant, see next section) CO_2 emissions from soil carbon stock change. They should be assigned and coded according to the descriptions in the Tables 4 and 5 in the previous Chapter 3.4.

The input section adds specific information to the questionnaire section “2.4 Mineral balance and fertilizer input” in order to allow capturing the details foreseen in the IPCC methodology. **Other organic N** (in kg/ha) is for example compost, sewage sludge and other organic N (others than the manure from on-farm beef production). The animal manure originating from the cow-calf and beef finishing must not be added here. All mineral N fertilisers should be noted (as a sum in kg/ha), as mentioned before, in the questionnaire’s section “2.4 Mineral balance and fertilizer input”. **Urea** (in t/ha) **Limestone** (in t/ha) and **Dolomite** (in t/ha) are listed for individual specification, as they represent an additional source of CO_2 in the system via their application and mineralisation.

All these inputs cause costs to the production enterprise. In order to account for it, do not forget to enter them in the questionnaire section “2.3 Variable Costs of Crop and Forage Production”.

The **land input** specifications per pasture/crop following the IPCC classifications are necessary to determine the soil carbon stock and (if land use change is relevant, see next section) CO_2 emissions from soil carbon stock change. They should be assigned and coded according to the descriptions in the Table 6 in the previous Chapter 3.4.

3.4.2 Past land use and management

Information about the historical land management (lines 3745 to 3791) is only necessary if a change in land use, land management or land input (according to the classifications in Tables 4-6) happened in the last 20 years. This default time frame is defined as the time period necessary to reach a new steady-state of soil carbon stock after a change of land use or management, according to IPCC. If a change happened prior to that time but diverging information about the time to reach the new steady-state suggest that it is not reached yet, it is also necessary to collect historical information. Besides the soil carbon stock and its change, this section in the questionnaire collects the necessary information to estimate the CO_2 emission released during the corresponding land use conversion.

As mentioned before, the codes from Tables 4-6 apply to this section, too, to classify the **previous land use**, the **previous land management** and the **previous land input**. In order to integrate this conversion information not only in a comparative static analysis, but also for the transformation analysis, it is helpful to know the **year of management change**. When the transformation period is simulated, it is possible to define based on this information from which year on, the steady-state has been reached and no further change of carbon stock applies to this fraction of the land.

In the case of land use change, the loss/gain of carbon stocked in vegetation cover is an important part of the carbon stock loss/gain, additionally to the potential loss/gain of soil carbon. In order to correctly estimate the vegetative carbon loss/gain, the **previous crop**/vegetation cover needs to be specified. As the possible variety of previous vegetation cover is quite high, the code list is not included in this document. It is part of the “EM-fin” and “EM-cc” Excel files, sheet “forest”. Please request support from the author or the *agri benchmark* Beef & Sheep head quarter team. The use of fire has a significant impact on the emissions released during conversion. It is therefore necessary to code (yes=1/no=0 coding) **if fire was used** for converting the previous vegetation. Additionally to the use of fire, the amount of biomass available prior to conversion is very important. If available, the **biomass of the vegetation prior to conversion** (in dry matter, t/ha) can be specified. If no information is available, this information will be taken from the default factors, available from IPCC. These are also part of the information of the “EM-fin” and “EM-cc” Excel files, sheet “forest”. Additionally it is possible to specify the amount of **harvested product (wood)** (in dry matter, t/ha) prior to conversion. If no information is entered, it will be assumed as 0. The amount of harvested product reduces the emissions from biomass lost due to fires during conversion.

These informations are collected based on the current land use and its acreage. If the previous vegetation of one current land use differ (and this land use change is still relevant for emission estimation), it might be useful to subdivide this specific area. If this is not possible, the majority of the current crop area’s history determines the classification and coding.

3.5 Additional data entry points in the INP

Some more data are required in the INP sheet. The common procedure foresees that these will be filled in by researchers as no specific farm-level information is needed.

Section Feed codes, line 10001 ff.

For all home-grown forage crops, a **crop residue code** (lines 10005 to 10025, column J) needs to be assigned so that the soil-related N_2O emissions can be estimated correctly. The crop residue codes refer to IPCC default crop factors for the estimation of N added to soils from crop above and below ground residues.

Table 7: Crop residue codes

	Description of crops and forages	Code number
Major crop types	Grains	1
	Beans&Pulses	2
	Tubers	3
	Root crops, other	4
	N-fixing forages	5
	Non-N-fixing forages	6
	Perennial grass	7
	Grass-clover mixtures	8
Individual crop types	Maize (corn)	101
	Wheat	102
	Winter wheat	103
	Spring wheat	104
	Rice	105
	Barley	106
	Oats	107
	Millet	108
	Sorghum	109
	Rye	110
	Soybean	111
	Dry bean	112
	Potato	113
	Peanut (w/pod)	114
	Alfalfa	115
	Non-legume hay	116
Forest and plantations	…	…

Source: Adapted from IPCC, 2006.

As the list groups several pastures and forages in broad groups, select the best matching crop code. This code-list excludes woody perennial crops, native forest vegetation and forest plantations. In case, woody components are relevant for beef production systems, e.g. in silvopastoral systems, these crop codes can be found in the “EM-fin” and “EM-cc” Excel files, sheet “forest”. Please request support from the author or the *agri benchmark* Beef & Sheep headquarter team.

Section Climate and whole-farm data, line 10047 ff.

The specification of the **climate region** (cell C 10061) is mandatory according to the IPCC terminology as it impacts the emissions from both, animal and soil. The IPCC climate zones are listed in the following table and base on elevation, mean annual temperature (MAT), mean annual precipitation (MAP), mean annual precipitation to potential evapotranspiration ratio (MAP:MET) and frost occurrence.

Table 8: IPCC Climate Zones

IPCC Climate Zones	Description
Tropical montane	MAT > 18; <= 7 days frost per year; elevation > 1000 m
Tropical wet	MAT > 18; <= 7 days frost per year; elevation <= 1000 m; MAP > 2000 mm
Tropical moist	MAT > 18; <= 7 days frost per year; elevation <= 1000 m; 2000 mm > MAP > 1000 mm
Tropical dry	MAT >18; <= 7 days frost per year; elevation <= 1000 m; MAP < 1000 mm
Warm temperate moist	18 > MAT > 10; MAP:PET > 1
Warm temperate dry	18 > MAT > 10; MAP:PET < 1
Cool temperate moist	10 > MAT > 0; MAP:PET > 1
Cool temperate dry	10 > MAT > 0; MAP:PET < 1
Boreal moist	0 > MAT > “all months < 10”; MAP:PET > 1
Boreal dry	0 > MAT > “all months < 10”; MAP:PET < 1
Polar moist	All months < 10; MAP:PET > 1
Polar dry	All months < 10; MAP:PET < 1

Source: Adapted from IPCC, 2006.

To account for soil carbon stocks and changes from land use and land management, the specification of the **prevailing soil type** (cell G 10061) is mandatory. The soil classification used by IPCC guidelines groups the soil types into six categories which are listed in the table below. Relevant information for the correct assignment can be found in soil maps. A farm should be assigned to the soil type representing the majority of its cultivated area.

Table 9: Mineral soil type classification

Soil type	Description
HAC	Soils with high activity clay (HAC) minerals are lightly to moderately weathered soils, which are dominated by 2:1 silicate clay minerals (in the World Reference Base for Soil Resources (WRB) classification these include Leptosols, Vertisols, Kastanozems, Chernozems, Phaeozems, Luvisols, Alisols, Albeluvisols, Solonetz, Calcisols, Gypsisols, Umbrisols, Cambisols, Regosols; in USDA classification includes Mollisols, Vertisols, high-base status Alfisols, Aridisols, Inceptisols).
LAC	Soils with low activity clay (LAC) minerals are highly weathered soils, dominated by 1:1 clay minerals and amorphous iron and aluminium oxides (in WRB classification includes Acrisols, Lixisols, Nitisols, Ferralsols, Durisols; in USDA classification includes Ultisols, Oxisols, acidic Alfisols).
Sandy	Includes all soils (regardless of taxonomic classification) having > 70% sand and < 8% clay, based on standard textural analyses (in WRB classification includes Arenosols; in USDA classification includes Psamments).
Spodic	Soils exhibiting strong podzolization (in WRB classification includes Podzols; in USDA classification Spodosols).
Volcanic	Soils derived from volcanic ash with allophanic mineralogy (in WRB classification Andosols; in USDA classification Andisols).
Wetland	Soils with restricted drainage leading to periodic flooding and anaerobic conditions (in WRB classification Gleysols; in USDA classification Aquic suborders).

Source: Adapted from IPCC, 2006.

Section Land use, line 10681 ff.

In order to estimate the CO_2 stock in soil and vegetation following a land-use change, enter the expected **conversion time** until the steady-state of the new land use or management is reached in the lines 10748 to 10768, column H. The default conversion time suggested by IPCC is 1 year for land use changes causing losses, e.g. forest to crop or grasslands and 20 years for land use changes causing gains, e.g. crop to grasslands or conventional tillage to reduce tillage.

4 Data collection

Greenhouse gas emissions from a beef production system depend on several variables. After the previous chapter explained how these information are captured in the insert file, this chapter intends to give some guidance in order to facilitate the preparation of data collection and the actual data collection in focus groups or expert interviews.

The subchapter 4.1 provides a list of necessary information to be collected to allow the estimation of greenhouse gas emissions and suggests appropriate information sources at farm level and beyond. The subchapter 4.2 targets the complexity of effects of mitigation strategies on production costs and performances. It suggests a scheme of indicators that might be affected and provides context via the exemplary discussion of selected mitigation strategies and their effects.

4.1 Data sources

The following table gives an overview of possible data sources that are available to farmers and / or researchers and that helps to give the best-informed answers to the questionnaire. It may also be helpful for the preparation of data collection and farmers or focus group interviews. It is a quite exhaustive list.

Table 10: Data sources

Typical farm				
Questionnaire section	**Required data**	**Main source**	by whom?	
			farmer	**research**
1.2 Machinery		Inventory list	x	
1.3 Buildings		Inventory list, farm plans	x	
1.4 Labour		Bookkeeping	x	
1.5 Liabilities/interest rates		(Public) bank information	x	x
1.6 Overhead costs		Bookkeeping	x	
2 Crop/Forage production		Crop/pasture management protocols	x	
4 Beef finishing		Animal registry, feed ratio description, sales/slaughter protocol, vet protocol	x	
5 Cow-calf		Animal registry, feed ratio description, sales/slaughter protocol, vet protocol	x	
Emission focus				
Questionnaire section	**Required data**	**Possible source**	by whom?	
			farmer	**research**

2.2 Land use, Yields, Prices	Yield per ha	Harvest records, pasture management protocols	x	
	Dry matter content	Farm individual feed analysis; feed databases	x	x
2.4 Mineral balance and fertilizer input	N in kg/ha	Pasture/crop management protocols	x	
	Calcium in kg/ha	Pasture/crop management protocols	x	
4.4 Feeding periods and rations	Feed ratio per animal and feeding group in kg/animal/day	Feed ratio description	x	
5.5 Rations for Suckler Cows and Calves	Feed ratio per animal category in t/animal/year	Feed ratio description	x	
9 Emissions				
9.1 Feed codes	Feed code: necessary for all purchased feed, or feed without cultivation information	Feed code list (FeedPrint)		x
	Digestibility code			x
	Dry matter content	should be used from section 2.2		
	Energy in ME, CP, Digestibility	Farm individual feed analysis; feed databases	x	x
	Crop residue code	IPCC crop list		x
9.2 Climate and whole-farm data	Climate data with temperature fluctuations and means	Weather stations, climate-data.org	(x)	x
	Climate region			x
	Soil type			x
	Electricity consumption (if possible, specify main source of electricity)	Bookkeeping	x	
	Fossil fuel consumption (if possible, specify main fuel type)	Bookkeeping	x	
	Manure use	Farmer’s knowledge	x	
9.3 Animal management	CC - Feeding situation, per animal category	Farm description, if multiple, please assign time in days/year, season	x	
	CC - Manure management system, per animal category	Farm description, if multiple, please assign time in days/year, season	x	
	if animal draught used: CC - Working hours	Farmer’s knowledge	x	
	if bedding supplied: CC - Bedding material per animal category, type and amount/day	Farmer’s knowledge	x	

	CC - milk yield figures (for dairy and suckler cows)	Milk delivery information; suckler cows: expert knowledge	x	x
	FIN: like CC, information per animal group and feeding period	see above	x	
9.4 Land management	Share of residues harvested in %, per crop	Crop management description	x	(x)
	Share of land renewed in %, per crop	Crop management description	x	(x)
	if burning: Area burned in ha, per crop	Crop management description	x	(x)
	Area exposed to leaching, per crop	Rainfall data		x
	if organic soil: drainage system, per crop	Foil classification, farmer's knowledge	x	(x)
	Land management and Land management, per crop	Farm description, maintenance/tillage		x
	Input of organic material in kg/ha, per crop	Pasture/crop management protocols	x	
	Input of urea, limestone, dolomite in t/ha, per crop	Pasture/crop management protocols, possible to transfer from section 2.4	x	(x)
	if management changes in the last 20 years: Land use history data with previous vegetation, previous management, previous inputs	Pasture/crop management protocols, farmers knowledge	x	(x)
	if management changes in the last 20 years: conversion period			x

Source: the author.

4.2 Assessing mitigation strategy implications

GHG mitigation strategies can be differentiated in technical strategies, management change strategies and a combination of both of them. The impacts on costs of production and economic returns of applying these strategies to an existing production system can be singular, but more often has multiple implications on investment, operational costs, productivity and returns. For a proper simulation of these implications, it is therefore necessary to collect all relevant information. Typical questions to understand the effects of a change to an existing question might be:

Direct costs

- Which **investment** is linked to this mitigation strategy?
- Does this mitigation strategy cause additional or increased **operational costs**?
- Does this mitigation strategy have an impact on **working hours**?
- Does this mitigation strategy require **additional knowledge** [that will be reflected in the cost of labour]?
- Will this mitigation strategy impact **land status** [which might have an economic implication on the land or rent value or opportunity cost]?

Indirect costs

- Which **prerequisites** need to be fulfilled so that a strategy can perform as expected?

Direct and indirect effects

- Does this mitigation strategy cause a change in **production, e.g. quantity or quality**?
- Does a mitigation strategy imply **additional returns, side- or by-products**?
- Do the effects of a mitigation strategy change the e**fficiency or productivity** of factor use?

To most effectively make use of the data collection, e.g. in a focus group discussion, the following Table 11 summarizes the typical effects of technologies and the linkages to the factors of an existing production system. It intends to help to properly prepare and streamline the data collection on mitigation strategies, reducing the forgotten impacts that would need to be added to the dataset afterwards.

Table 11: Effect scheme of mitigation strategies

Mitigation strategy			
Direct costs	Direct returns	Indirect costs - prerequisites	Indirect returns – side effects
Investment in…	**Animal performance** changes in…	Need to be identified based on the specific conditions of the farm, e.g. … …quality and quantity of feed available …genetic potential of animals …skills of employed labour …available services	**Efficiency change** in…
…machinery	…daily weight gain		…feed conversion rate
…buildings	…carcass yield		…pasture growth use
…equipment and facilities	…growth potential/final weight		…age of first calving
Operational expenditures for …	…pregnancy rate		…replacement rate
…animals	…calving percentage		**Productivity change** possibly changes opportunity costs via…
…feed	…mortality		…labour productivity (e.g. kg produced/hour)
…vet services/animal treatment	**Pasture production** changes in…		…land productivity (e.g. kg produced/ha)
…pasture/crop cultivation	…yield		…capital productivity (e.g. return on investment)
…whole farm inputs (electricity, fuel,…)	…carrying capacity		**Quality change** of product and process leads to...
Quantity and quality of…	…nutritional values		…price premium, e.g. high quality score for beef
…labour	**Additional production** of…		…valuable side product, e.g. manure
…land	…pasture/crop/timber yields (for sale)		
…capital	…energy		

Source: the author.

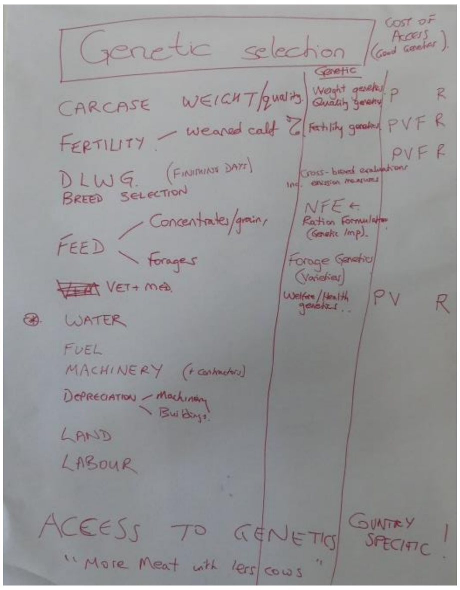
The following examples intend to contextualise this effect scheme. They are the results of four working groups hold during the workshop “GHG mitigation in beef production – Integrating climate impact and economics on farm level” animated the Beef and Sheep Conference (BSC) 2019. The session's participants were asked to simulate the impact of four relevant mitigation strategies on beef production systems (improved genetics, improved feeding, pasture restoration and manure management) on production costs (fix and variable) and on the production system's performance and returns. Although the results do not give the actual costs or prices, they quite comprehensively identify all relevant cost positions and performance indicators (for which the researcher would have to assign costs and quantities).

Improved genetics

Improved genetics, through selective breeding and / or artificial insemination, represent a major strategy to make beef production more efficient, more resilient or more adapted. Having this in mind, the related cost positions are identified quickly, however, the effects on direct and indirect returns depend strongly on the selection goal. Besides a description of the transition period, when starting to apply this strategy in an existing cow herd, would have to discuss how fast the desired traits will become effective.

During the workshop a broad range of breeding goals has been discussed. The results elaborated during the workshop session (Figure 3) are transferred to the table scheme adapted from Table 11.

Figure 3: Results of BSC 2019 workshop



Source: agri benchmark BSC 2019, Windhoek, NA.

The cost of access to good genetics is a major prerequisite, as it requires reliable infrastructure and services outside the farm. The access to good quality feed and supplements that are often necessary if genetic selection aims to increase yields and productivity goes hand in hand with this first requirement.

Depending on the aim of genetic selection and the farm production (cow-calf or finishing), different investments, performance improvements or returns need to be considered. Taking “more meat less cows” as the guiding principle of improved genetics, higher animal efficiency leads to an increase in productivity of production factors, leading to an increase of return on investment.

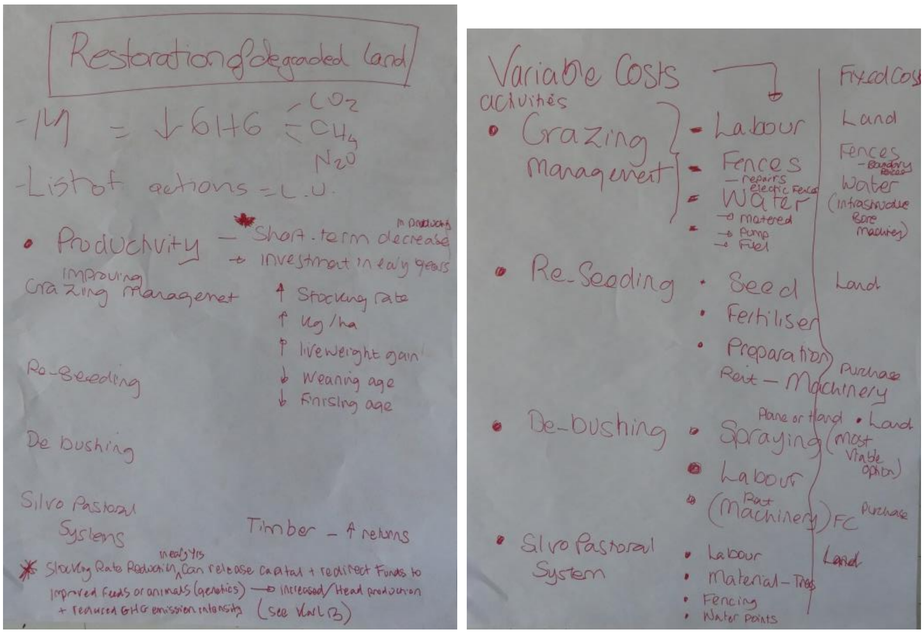
Table 12: Effects of the mitigation strategy “Genetic selection”

Genetic selection, improved animal genetics (for weight, quality, fertility)			
Direct costs	Direct returns	Indirect costs - prerequisites	Indirect returns – side effects
Investment in…	**Animal performance** changes in…	Cost of access to good genetics/available services Quality and quantity of feed available	**Efficiency change** in…
-.more places for animals/calves	- daily weight gain		- feed conversion rate
Operational expenditures for …	- final weight		- age of first calving
- vet services/animal treatment	- carcass yield		**Productivity change** via…
- purchase of feed (forages and concentrates/grains) meeting the animals requirements	- calving percentage		- labour productivity: more meat/working hour
- water consumption	- number of animals sold		- capital productivity: increase of return on investment in feed, machinery and buildings (shorter finishing period with higher turn-around)
- fuel to manage increased herd			**Quality change** of product and process leads to...
			- carcass quality

Restoration of degraded grasslands

Restoration of degraded grasslands as a single mitigation strategy is very complex, as it implies several actions that are necessary to reach the final goal of restored grasslands. During the working group, restoration of degraded land was subdivided into the activities: grazing management (on degraded and restored land), re-seeding, de-bushing, and integration of silvopastoral elements as an improvement to the common grassland management practices.

Figure 4: Results of BSC 2019 workshop



Source: agri benchmark BSC 2019, Windhoek, NA.

The productivity as one of the targets of this strategy is expected to decrease in the short term due to less area available for grazing and reduction of stocking rate of remaining land before increasing after restoration.

The results elaborated during the workshop session (Figure 4) are transferred to the table scheme adapted from Table 11.

Table 13: Effects of the mitigation strategy “Restoration of degraded grassland”

Restoration of degraded grassland			
Direct costs	Direct returns	Indirect costs - prerequisites	Indirect returns – side effects
Investment in…	**Animal performance** changes in…	Adopted pasture seeds available	**Efficiency change** in…
- fences (stationary, boundary, mobile) and gates	- daily weight gain	Legal conditions (land rights)	- pasture growth use
- water system, bore hole, pumps, pipes and reservoirs	- weaning age		**Productivity change** via…
[- machinery for seeding, fertilisation, de-bushing]	- finishing age		- land productivity (e.g. kg produced/ha)
Operational expenditures for …	**Pasture production** changes in…		**Quality change** of product and process leads to...
Fuel for watering pumps	…yield and nutritional values		- land value increase, increase of opportunity costs
Seed, fertiliser, herbicides/arboricides [contractor costs]	…carrying capacity		
Seedlings (trees)	**Additional production** of…		
Repairs and spare parts for (electric) fences, watering points, machinery	- timber when integrating silvopastoral elements		
Quantity and quality of…			
- labour for animal management			
- labour for fencing, water system installation			
- labour for pasture management			

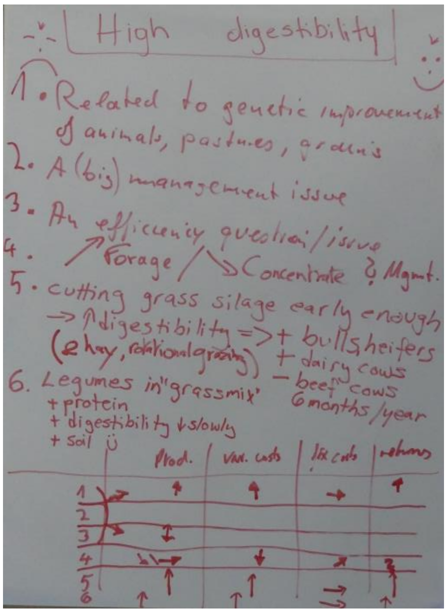
The process of pasture restoration is time intensive and requires substantial investment. Additionally, a certain risk of failure is present as it depends heavily on environmental conditions that are in most cases hard to control or compensate (e.g. unexpected precipitation patterns). If the transition process is to be modelled, this complexity should be considered in a) how much investment (labour, capital, land) is possible per year, b) how would farmers cope with risks of failure and c) how many years will the process take (considering a consecutive restoration of smaller land fractions until the total area is restored).

During the transition period, several factors can interact and support each other. The reduction of socking rate in early years in order to adapt to low productivity of degraded land can release capital from animal purchase that is e.g. redirected to the purchase of supplementary feed or animals with improved genetics. This enables to increase the productivity per head and thus (partly) compensate the losses (animal number and economic) while at the meantime reducing the greenhouse gas emission intensity per kilogram meat produced.

Increased feed digestibility

The enteric fermentation is the most important source of greenhouse gas emissions from beef production systems. Higher digestible feed reduce the methane yield factor and thus have a substantial effect on the emissions per animal. Besides, high digestible feed benefits the beef production. During the workshop, the working group discussed different ways to increase the feed digestibility, including the replacement of concentrates by high quality forage, the optimal timing of grass cutting and storage and enrichment of pastures/grass forage with legumes.

Figure 5: Results of BSC 2019 workshop



Source: agri benchmark BSC 2019, Windhoek, NA.

The genetic production potential of animals, pastures and other forages, the proper management skills to make full use of these resources and the question about effectiveness of this strategy have been identified as pre-requisites. The results elaborated during the workshop session (Figure 5) are transferred to the table scheme adapted from Table 11.

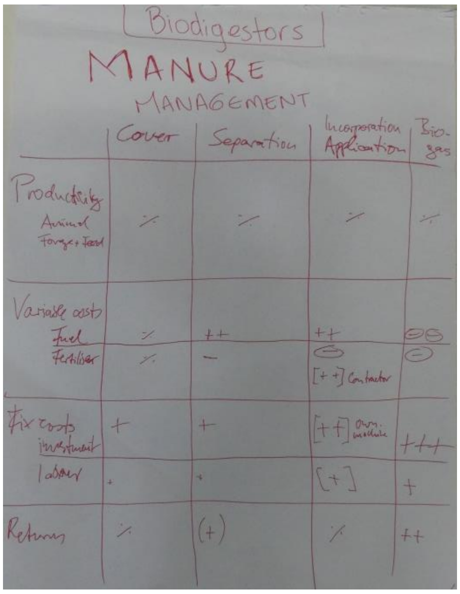
Table 14: Effects of the mitigation strategy “Increased feed digestibility”

Increased feed digestibility			
Direct costs	Direct returns	Indirect costs - prerequisites	Indirect returns – side effects
Investment possibly in…	**Animal performance** changes in…	Potential for further improvement of the current feeding situation	**Efficiency change** in…
- more storage room: for forage, if concentrate replacement	- daily weight gain		- feed conversion rate
- machinery for harvesting, conservation	- finishing period	Genetic potential of breeds to metabolise high digestible feed	- pasture growth use
Operational expenditures for …	- milk production	Genetic potential of pastures and forages mixes to produce high digestible and high nutritive feed	**Productivity change** via…
- concentrates (decrease with more high digestible forage)*	*Forage/concentrate replacement might be with no/ negative effect	Management skills to make use of production factor potential	- capital productivity (higher turn-around of animals)
- legume seeds [reduced fertilizer]	**Pasture production** possibly changes in…		- land productivity (kg produced/ha)
- pasture seeds, fertilizer, fuel for frequent cutting	- yield and carrying capacity [regular cutting increase total production]		**Quality change** of product and process leads to...
- feed and forage testing, nutritional analysis	- nutritional values [especially with legume inter-seeding]		Soil improvement due to legume in pasture
Quantity and quality of…			
- labour: additional skills on timings, feed storage and feeding according to needs			

Manure management, e.g. biodigestors

Manure management strategies are probably among the least impacting mitigation strategies. In production systems that keep animals confined during at least some period of the year, they represent an additional mitigation option for methane and nitrous oxide from excreta. In pasture based systems, they are usually not considered due to the high costs for manure collection that would occur.

Figure 6: Results of BSC 2019 workshop



Source: agri benchmark BSC 2019, Windhoek, NA.

The results elaborated during the workshop session (Figure 6) are transferred to the table scheme adapted from Table 11.

Compared to the previously described mitigation strategies, an investment in manure management is much less complex and easier to estimate for a production system. Additionally it is usually a yes-no decision with a direct impact, not requiring consider a transition period before the effects comes into action. The type of costs is rather a one-time investment, with few operational costs, however this depends on the possibility to hire a contractor. The impact on animal production and pasture or crop production is low or neglectable, however in case there is a market, it opens up new income opportunities.

Table 14: Effects of the mitigation strategy "Manure management"

Manure management				
Direct costs	Direct returns		Indirect costs - prerequisites	Indirect returns – side effects
Investment in…	**Additional production** of…		Confined systems	**Quality change** of product and process leads to...
- storage cover, biogas plant (additional storage, fermenter, engine,…)	- high density organic fertiliser			- reduced electricity consumption due to heat usage from manure fermenter
- separator machine, spreader with direct incorporation	- electricity (for sale and/or own consumption)			- valuable side product, e.g. solid manure
Operational expenditures for …				
- fertilizer decrease				
- contractor costs if no own machines				
- transport costs if cooperation and no own facilities				
- fuel for separation, incorporation				
Quantity and quality of…				
- labour: high for biogas, low for cover technology, solid separation and incorporating application				
- capital				

•

5 Literature

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