THIRD NATIONAL COMMUNICATION

CAPACITY BUILDING WORKSHOP - AGRICULTURE AND LAND USE (ALU) NATIONAL GHG INVENTORY SOFTWARE VERSION 5.0

24 – 28 July 2017
University of Mauritius, Reduit

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1.0 Background

Mauritius, as a signatory Party to the UNFCCC, has certain obligations, namely reporting on the country's efforts to implement the Convention. The reporting requirements have substantially evolved in the recent years and are now more stringent for developing countries. The reports consist of the Biennial Update Report (BUR) every two years, with the first one due in 2014, in addition to the National Communication (NC) every four years.

The Government received GEF grant funding to conduct the preparation of the Third National Communication (TNC) and the National Inventory Report (NIR), in accordance with reporting obligation of Parties under UNFCCC. During the GHG inventory process for the NIR, the Technical Working Group (TWG) on Agriculture, Forestry and Other Land Use (AFOLU) raised concern on the data collection/availability to move to higher tier levels in the 2006 IPCC Software.

It has come to our knowledge that the revised Agriculture and Land Use (ALU) software version 5.0, could be used to conduct GHG inventory in the AFOLU sector to produce refiner GHG results. This is acceptable to the methodology for this sector as per the 2006 IPCC Guidelines for National GHG inventories.

In view of the need to build sustainability at the institutional level process in terms of refining/upgrading the GHG inventory in this sector, the AFOLU stakeholders expressed their wish to get training on same as part of capacity building under TNC.

2.0 Overall Objective

To train local designated personnel involved within the Agriculture, Forestry and Other Land Use (AFOLU) sector on the use and application of the ALU software, which is designed to refine the level of detail in GHG inventories, that is, estimate emissions and removals associated with biomass Carbon stocks, soil Carbon stocks, soil nitrous oxide emissions, enteric methane emissions, manure methane and nitrous oxide emissions, as well as non-CO2 GHG emissions from biomass burning. Methods are based on the 2006 IPCC Guidelines for National Greenhouse Gas Inventories.

2.1 Specific Objectives

a) To provide hands-on training for each module (activity data, emission factors and calculations) in the ALU software;
b) To review the utilities provided for data management;
c) To generate emissions reports from the software; and
d) To discuss any issues of concern such as development of country-specific emission factors and filling gaps in activity data.

3.0 Working Sessions

The working sessions was spanned over 5 days at the CITS Computer Laboratory Ex-Student Common Room, University of Mauritius, Reduit. The training were devoted to the technical component of entering data for the Agriculture (Crop and Livestock), the Forestry and Other Land Use sectors and running the ALU software Version 5.0. The meeting was attended by 21 members of the Mauritian GHG inventory team in the AFOLU sector and 1 resource person (Dr Stephen Ogle). A copy of the list of participants is at ***ANNEX I*** and the Programme is at ***ANNEX II***.

4.0 Opening Remarks (Venue: Lecture Theatre 1, University of Mauritius, Reduit)

Mr. J. Seewoobaduth, Divisional Environment Officer of the Climate Change Division welcomed all stakeholders on behalf of the Ministry of Social Security, National Solidarity, and Environment and Sustainable Development (Environment and Sustainable Development Division). He then invited the Honourable Etienne Sinatambou, Minister of Social Security, National Solidarity, and Environment and Sustainable Development, to open the ALU capacity building workshop.

The Honourable Minister welcomed all participants from the various Ministries, private sectors and NGOs. He extended his profound gratitude to UNEP and GEF for their unwavering support as well as technical and financial assistance extended to Mauritius for this project. He also welcomed Dr Stephen Ogle who is an international expert and resource person on application of greenhouse gas inventory methods. He emphasized that training would be a knowledge transfer exercise meant to enable Mauritius to bring improvement in its greenhouse gas inventory in order to assess as precisely as possible our greenhouse gas emissions and carbon sequestration potentials. He humbly requested the participants to make proficient use of the knowledge that will be gathered during this training workshop. He then declared the workshop opened. A copy of his speech is given at ***Annex III***.

5.0 Presentation: Introduction to Agriculture and Land Use National Greenhouse Gas Inventory Software – Dr Stephen Ogle

Dr Ogle delivered his presentation at ***Annex IV***. He pointed out that in 2013, the net GHG emissions for the Republic of Mauritius, including the Forest and Other Land Use (FOLU) sector, was estimated to be 4,758 CO_2-eq and the Agriculture (livestock and use of fertilizers) contributed 2.7% of total emissions. The removal of carbon dioxide was around 368 Gg in 2013. He highlighted the methodologies applied in the previous GHG Inventories for AFOLU Sector, the TACCC (Transparency, Accuracy, Consistency, Comparability and Completeness) Principles followed by introduction to the ALU Software.

6.0 Technical Session in ALU Software Version 5.0

Participants were led through a session associated with getting started in the ALU software, loaded the software on the computers, including setting up a user name, a session (geographical area plus inventory year), and using the manual. For the rest of the workshop, participants worked with sessions on the computers using data for 2013 compiled by the Mauritian group that had been facilitated by the resource person. A copy of the presentation delivered by Dr Ogle during the technical session is at ***Annex V***.

6.1 Soil Amendments

Data entry from nitrogen was based on N applied to food crops and on recommended rates and area under cultivation for sugarcane. It was inferred that N fertilizers were also used for golf courses, backyard gardens, orchards, and these have not been accounted for in the statistics. Participants then entered the values for nitrogen fertilisers (imports) in Module I, followed by emission factors (EFs) relevant to urea CO_2 emissions in Module II and were shown how to compute calculation in Module III.

6.2 Livestock and Manure Management

The livestock expert had obtained data on livestock numbers for 2013 from the official national statistics. These data were entered into the ALU software.

Participants then entered nitrogen excretion rates and emission factors relevant to livestock and manure management using IPCC defaults. They were then shown how to complete calculations for methane emissions from livestock and manure and completed calculations.

Notes

- Cattle: Source: FAREI; MMA Annual Report Importation; Digest of Agricultural Statistics
- Goat: Digest of Agricultural Statistics; MMA Annual Report Importation
- Sheep: Digest of Agricultural Statistics; MMA Annual Report Importation
- Pigs: Digest of Agricultural Statistics;
- Deer: Estimated figure from FAREI
- Poultry: Food Balance sheets; APD; MAIFS
- Horses: Mauritius Turf Club

6.3 Land Use

Climate, soil, land use and land use subcategory (e.g., forest types) data were manually entered in the software as the training and preparation of files from the excel sheets prepared by the FOLU stakeholders. The land use and land use subcategory data were collated from various sources.

The table below summarises the land use categories which was adopted during the ALU Training Session:

Land Use	Area (hectares)
Forest Land	47,286
Cropland	65,967
Grassland	1,779
Wetland	3,690
Settlement	28,879
Other Lands	38,881
Forest Land to Settlement	1
Forest Land to Other Lands	33
TOTAL	186,516

There was also a session on how to input the land use data using GIS file.

Notes

- Source of Land Use Data: Ministry of Agriculture, Ministry of Housing and Lands; Digest of Agriculture;
- It also comes from the annual Report of Forestry Service.
- Settlements: unpublished data.
- Mangroves are included in Forestland.
- Settlements area data based on districts area of Mauritius and Population Census 2011.
- Climate and Ecological Zones, and soil type based on opinion of workshop participants.
- These data need to be updated from a GIS analysis of settlements cover data, climate, soils and ecological zones.
- Settlements cover not sub-divided into classes for categories such as grass, infrastructure, urban forests, etc. These need to be done in order to estimate source of carbon stock changes in settlements.
- Wetlands Data based on ESA Study 2009 (should do quality control and check for updated data)
- Other Land area needs to be more disaggregated (update settlements, wetlands).

6.4 Forestland

Forestry activity data were entered for the gain-loss method and the full set of calculations were completed using default factors from the IPCC. Forest data was inputted in the ALU software based on climate (tropical dry and tropical moist); Ecological Zone (tropical dry forest and tropical moist deciduous forest); Soil (Low Activity Clay and sandy mineral); age class (<20years and >20years). Additional information was inputted in the ALU Software for forest disturbance by fire, timber harvesting and fuel wood gathering.

Deforestation is not common in Mauritius and was not estimated because of only one time-step in the land use data. For stand disturbance by fire, data were entered for only one particular site where burning occurs annually. Timber harvest and fuelwood data were compiled by tree species from data records managed by the Forestry Service.

Notes

- Source of Forestry Data: Annual Report Forestry Service; Records Office of Forestry Service
- Source data: Soil Map from Land Use Division; Climate Map (METEO to check); Ecological Zone from the Forestry Service based on FAO classification.
- Wood removal data are from registered wood cutting permits. Wood removal includes some fuelwood collection because branches and upper part of tree are often collected for this purpose during harvest. Therefore we assumed that only one-third of fuelwood collection was from trees that were not harvested for wood removals.
- No shifting cultivation occurs in Mauritius based on opinions of workshop participants.

6.5 Cropland

During the NIR process, data were collected on the areas under different perennial and annual crops as well as the management systems. Sugarcane and a few of the other main crops were treated separately and the remainder of the cropland was assumed to be used for production of general vegetables. Food crop rotations were treated as opportunistic (i.e., not an explicit rotation, but a general set of crops that are typically grown on a land parcel for food production) based on the food demand at the time, but general rotations were described based on the dominant crops. Data on all the cropping systems and management were entered, emission factors assigned and emissions calculated.

Notes

- Cropland area data are from Statistics Mauritius, Digest of Agricultural Statistics, 2014.
- Climate, ecological zone and soil are based on opinion of workshop participants (need to be revisited in future).
- The crop management systems are based on an aggregation of crop production data from Digest of Agricultural Statistics, 2014, Statistics Mauritius.
- The rotation data is based on inventory compilers expert knowledge.
- The rotations assumed there is a diversity of crop cultivated on the same land and so there are no well-defined rotations.
- Perrenial crop maturity based on opinions of workshop participants.
- Data on tillage, residue management and other practices for crop systems is based on opinions of workshop participants (need to be checked in future through surveys by experts/ crop management survey or look at other policy issues) can include this information in SM surveys.

6.6 Grassland

Grassland in Mauritius consists mainly of open grassland (golf courses, recreational grounds, parks and gardens). Hence, grasslands do not bear that much importance and have little bearing on emissions as there is also no burning. There will be some changes in C stocks with land use change, but these data were not available, but the team plans to compile more detailed information in the future using RS imagery to track land use and land use change.

Notes:

- Grassland data based on Statistical Digest, Fisher et al. Study, 2009 and MCIA/MSIRI map.
- Climate and Ecological zones and soil types based on opinions of workshop participants (need to be checked).
- Grassland Management System areas based on opinions of workshop participants (need to be revisited in future)
- Grassland soil carbon management based on opinions of workshop participants (need to check in future)

7.0 Award of Certificate

The award ceremony for handing over certificates to participants was held on the last day (Friday) afternoon session. The ceremony was chaired by Mrs Goorah, the Permanent Secretary of the Environment and Sustainable Development Division. A copy of the ALU Training Certificate is at ***Annex VI***.

Annex I: List of Participants in ALU Workshop

Name	Designation/Organization	Contact Information
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Annex II: Workshop Programme

THIRD NATIONAL COMMUNICATION

Capacity Building Workshop - Agriculture and Land Use (ALU) National GHG Inventory Software Version 5.0

24-28 July 2017

Day 1

Venue: Lecture Theatre 1

9:00 – 10:00 Registration/Stakeholders Networking & Tea Break

10:00 – 10:15 Opening Address by Hon. Minister

10:15 – 12:00 Introduction to Agriculture and Land Use National Greenhouse Gas Inventory Software, Version 5 (2006 IPCC Guidelines Version) – Dr Stephen Ogle, Colorado State University

12:00 – 13:00 LUNCH

CITS Computer Laboratory Ex-Student Common Room

13:00 – 13:30 Loading Software on Computers, Overview of Interface and Data Entry

13:30-14:30 Soil N_2O Emissions from Synthetic Fertilizers, and CO_2 Emissions from Liming and Urea

14:30-15:15 Enter Basic Characterization for Livestock

15:15-15:45 TEA BREAK

15:45-17:00 Module II and III Enteric Methane, Manure Methane and Nitrous Oxide, and Soil N_2O from Manure

Day 2

9:00-10:00	Complete Livestock and Manure Emissions Emissions
9:00-10:30	Overview of Land Representation
10:30-11:00	**TEA BREAK**
11:00-12:30	Enter Land Representation Data
12:30-13:30	**LUNCH**
13:30-15:00	Continue Land Representation Data
15:00-15:30	**TEA BREAK**
15:30-17:00	Enter Cropland Management Data

Day 3

9:00-9:30	Complete Cropland Management Data
9:30-10:30	Enter Biomass Management Data
10:30-11:00	**TEA BREAK**
11:00-12:30	Module II and III for Biomass C Stock Changes
12:30-13:30	**LUNCH**
13:30-15:00	Continue Biomass C Stock Changes
15:00-15:30	**TEA BREAK**
15:30-17:00	Enter Crop Residue Management Data

Day 4

9:00-10:30 Module II and III for Non-CO_2 Emissions from Burning and Soil N_2O Emissions from Residue Management

10:30-11:00 TEA BREAK

11:00-12:30 Overview of Soil C Management Data

12:30-13:30 LUNCH

13:30-15:00 Enter Soil C Management Data

15:00-15:30 TEA BREAK

15:30-17:00 Complete Soil C Management Data

Day 5

9:00-9:30 Module II and III for Soil C

9:30-10:30 Enter a Second Year of Soil C Management Data

10:30-11:00 TEA BREAK

11:00-12:30 Complete Soil C Stock Changes

12:30-13:30 LUNCH

13:30-15:00 Overview of Uncertainty Analyses and Example in ALU Software

15:00-15:30 TEA BREAK

15:30-16.30 Complete Uncertainty Analysis Example

16:30- 17:00 Award of Certificates & Workshop Closure

Annex III: Speech of Opening Ceremony by Hon. Minister

- A very good morning to all of you. I am very honoured to be in your midst today for this workshop which is aimed at training all relevant stakeholders on the inventory of greenhouse gas emissions from the Agriculture, Forestry and Land Use sectors also referred to as AFOLU using the latest available Agriculture and Land Use (ALU) software. This training workshop is being undertaken with a view to enhance institutional capacity in concerned institutions, in Mauritius including Rodrigues, to enable reporting of greenhouse gas emission as well as sequestration.

- In this respect, the Government acknowledges the funding received through the United Nations Environment Programme (UNEP) and the Global Environment Facility (GEF) under the Third National Communication project. I would like to extend my profound gratitude to these 2 institutions for their unwavering support.

- Allow me to extend a very warm welcome to Dr Stephen Ogle who is an international expert and resource person on application of greenhouse gas inventory methods. I understand that he is from the Colorado State University and serves as lead compiler for the US national inventory for soil carbon and nitrous oxide emissions from agricultural lands. We are fortunate to have him to lead us through this 5-days training workshop. I am convinced that our valued stakeholders will optimise on the presence of Dr Ogle and will gain as much as possible from his experience and knowledge. Dr Ogle, I also hope that you will have the opportunity to visit around and enjoy the beauty of our island during your stay.

Ladies and gentlemen,

- Allow me to remind us that this timely support is instrumental for a Small Island State like Mauritius to fully engage ourselves on the international front in order to combat climate change as per our pledges under the United Nations Framework Convention on Climate Change (UNFCCC) and the Paris Agreement. This training is also a knowledge transfer exercise meant to enable Mauritius to bring improvement in its greenhouse gas inventory in order to assess as precisely as possible our greenhouse gas emissions and carbon sequestration potentials.

- I cannot stop reiterating that climate change remains one of the most serious and pressing challenges that mankind is facing. It represents a major impediment on the pathway of sustainable development and with the worsening tendency, it is most likely that its adverse impacts would be among the most serious hurdles in the achievement of sustainable development goals for vulnerable countries like Mauritius.

- Coming to the root causes of global warming and climate change, we are all aware that greenhouse gas emission is the main source of accelerated global warming and climate change. Some time ago, I shared with you this information about global greenhouse gas emissions. You may recall that the latest UNEP's Emissions Gap Report released in November 2016 indicated that the most recent estimates for greenhouse gas emissions amount to 52.7 gigatonnes of carbon dioxide equivalent in 2014. On the other hand, in order to limit the temperature rise to less than 2 degrees Celsius, the global greenhouse gas emissions in the year 2020 should not be higher than 44 gigatonnes of carbon dioxide equivalent. However, it is very likely that with developments occurring globally at the current pace under the present business as usual scenario, that is, a continued rise in emission from industrialised countries, there would be an emission gap of around 8 gigatonnes or more of carbon dioxide equivalent by 2020 thereby narrowing opportunities to keep temperature rise to well below 1.5 degree Celsius, as being strongly advocated by vulnerable Small Islands Developing States (SIDS), Least Developed Countries (LDC) and countries of Africa.

- Likewise, the latest figures confirm the above concerns. For instance, the *National Aeronautics and Space Administration* (NASA) reported that the atmospheric concentration of carbon dioxide rose to reach a new record high of 406 parts per million in May 2017. As greenhouse gas is rising, the surface temperature too is rising steeply and new records are being attained in a fairly short lapse of time.

- As far as the earth global average surface temperature is concerned, the *National Oceanic and Atmospheric Administration* (NOAA) confirmed that 2016 was the warmest year since modern recordkeeping began in 1880. The resulting extreme weather means that the impacts of climate change on people and their livelihoods are happening much sooner than anticipated and with greater severity.

- The imbalance caused by the rising greenhouse gas and the resulting global warming are aggravating global climate. Extreme climatic events are being observed daily in every corner of the planet. On one hand, we are witnessing prolonged and severe heatwaves that resulted in deadly forest fires in Portugal and Spain a few weeks ago which has caused the death of some 64 people in in Portugal and has forced the evacuation of some 1,500 people in Spain. Soaring temperatures were also recorded in other parts of Europe namely in England, France and Belgium over the past few weeks. In this regard, UK authorities have warned that these persistent high temperatures could see annual heat-related deaths to more than triple to 7,000 by 2040. On the other hand, Japan and China have been hit by days of intense rain which have resulted in flooding and landslides across these countries. Two deaths and 18 people went missing in Japan while 50 deaths and 1.2 million people were evacuated in China.

Ladies and gentlemen,

- In light of these stark warnings that cannot be ignored, tougher actions on climate change are urgently needed to prevent the world speeding towards a catastrophic path. Indeed, you will recall that the Paris Agreement was the first-ever universally accepted breakthrough climate deal. To-date 153 countries have ratified the agreement which defines the global objective of "holding the increase in the global average temperature to well below 2°C above pre-industrial levels while pursuing efforts to limit temperature rise to 1.5^{o}C by the year 2100".

- In this regard, it is worth mentioning that although Mauritius' contribution to global emissions of GHG stood at around 0.01% last year, the irony is that we are being disproportionately impacted. According to the latest World Risk Report 2016, Mauritius is ranked as the 13th country with the highest disaster risk and ranked 7th on the list of countries most exposed to natural hazards. However, in a spirit of solidarity and as a moral obligation to save our planet from heading on a dangerous climate change pathway all developing countries, including Mauritius, have been called upon to take measures to mitigate climate change according to their respective capabilities.

- In this regards, *Intended Nationally Determined Contributions* for Mauritius is pledging to abate greenhouse gas (GHG) emissions by 30% by the year 2030, relative to the business as usual scenario, by transitioning to a low-carbon development path through the accrued utilisation of renewable energies but subject to provision of grant finance, technology development and transfer, and capacity building. To totally fulfil our contributions and achieve climate change resilience through the implementation of adaptation and mitigation measures, financing of the order of USD 5.5 billion will be required.

Ladies and gentlemen,

- In light of these facts, this Government is determined to do its fair share to put Mauritius on the track of sustainable development by fully promoting a low carbon economy pathway as well as building resilience against the growing threats of climate change. In this regard, I wish to point out that this Government has already identified a series of bold measures to contribute to abating our GHG emissions and strengthened adaptation to climate change impacts. From the agricultural sector point of view some key audacious measures have been identified in the 2017-2018 budget which are as follows:
    - We are encouraging the revival of tea cultivation and export;
    - The setting up of greenhouses for crop production on agricultural land will be exempted from the need to obtain a Building & Land Use Permit;

- The *Development Bank of Mauritius* will provide loans facilities to planters whose crops are damaged by climatic conditions, pests and diseases; and
- To boost the bio-farming sector, all costs associated with the registration of a Bio-farming Development Certificate would be provided in view for farmers to acquire an international organic label and the cost of bio-pesticides will be subsidised.

- Additionally, we are promoting smart agriculture practices with regard to improving water use efficiency, integrated pest management and organic agriculture in the crop production sector. It is noteworthy that we are also working towards improving the resilience of small farmers in Rodrigues, Agalega and Mauritius through an EU funded *Global Climate Change Alliance* programme. The programme will increase the knowledge and enhance adaptation of farmers to climate change impacts in order to contribute to more sustainable livelihoods.

- Ladies and gentlemen,

  I understand that this capacity building workshop will help to review activity data of the AFOLU sector, including hands-on training emission factors and calculations using the latest Agriculture and Land Use software, review of the utilities provided for data management and directions on how to make emissions reports from the software. We also look forward for this training to provide solutions to overcome limitations concerning the inventory of carbon sequestration in trees on private lands, river and mountain reserves as well as trees in public places including schools, hospitals and roadsides.

- Ultimately, this capacity building will allow technical staff of my Ministry as well as our relevant stakeholders to be more effective in future reporting exercises namely the forthcoming Biennial Update Report. We also hope to be able to develop country-specific emission factors.

- With this bigger picture in mind, I humbly request the participants to make proficient use of the knowledge that will be gathered during this workshop.

- With these words, I thank you all for your kind attention and I now have the pleasure to declare the workshop open.

E.S

Annex IV: Presentation on Introduction to ALU Software

Introduction to Agriculture and Land Use National Greenhouse Gas Inventory Software, Version 5 (2006 IPCC Guidelines Version)

Dr. Stephen Ogle, Ph.D.
Senior Research Scientist and Professor
Natural Resource Ecology Laboratory
Colorado State University

ALU Software Training Workshop

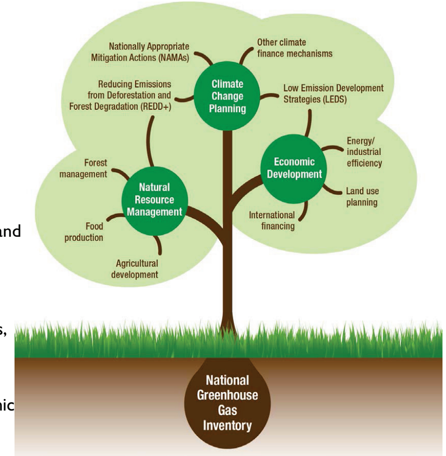
NATURAL RESOURCE ECOLOGY LABORATORY

Why compile a National GHG Inventory?

Build a Solid Foundation for Low Emission Growth

"Can't manage what you don't measure"

- Understand national GHG emissions, removals and trends
- Identify cost-effective policies and programs to reduce emissions, while enhancing climate resiliency
- Meet international obligations and participate in future GHG programs and agreements (UNFCCC reporting)
- Enhance environmental integrity of mitigation options (baselines, BAU emissions/projections, REDD+, NDCs, LEDS, etc.)
- Useful indicators for environmental assessment and management, economic development and planning



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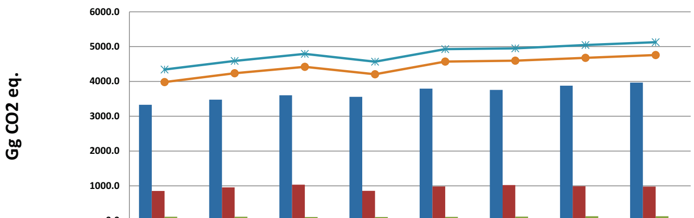
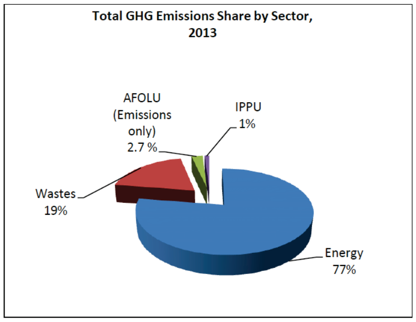
Total GHG Emissions for Mauritius



	2006	2007	2008	2009	2010	2011	2012	2013
Energy	3327.8	3477.1	3601.1	3555.6	3791.2	3754.5	3876.7	3965.2
Waste	854.3	955.2	1034.6	857.2	980.6	1022.3	990.5	979.3
AFOLU - Agriculture	115.0	112.7	106.8	104.4	108.4	116.5	126.6	127.4
IPPU	42.9	44.6	46.6	48.5	48.2	55.5	51.2	54.0
Total -exc LULUCF	4340.1	4589.6	4789.0	4565.7	4928.4	4948.8	5045.1	5125.9
Total - inc. LULUCF	3978.7	4235.0	4417.5	4203.5	4570.3	4594.2	4675.0	4758.4

In 2013, the net Greenhouse Gas (GHG) emissions for the Republic of Mauritius, including the Forest and Other Land Use (FOLU) sector, was estimated to be 4,758 Gigagramme of carbon dioxide equivalent (CO2-eq) compared to 3,979 Gg CO2-eq in 2006.

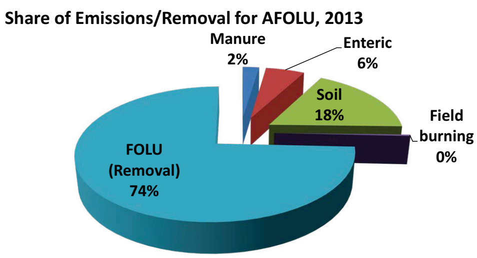
Share of GHG Emissions by Sector for Mauritius



- In 2013, the Energy Sector was the main source of GHG emissions, amounting to 77% of overall GHG emissions (excluding FOLU) followed by Waste sector (19%). Agriculture (livestock and use of fertilizers) contributed 2.7% of total emissions in 2013.
- The removal of carbon dioxide was around 368 Gg in 2013.

GHG from Agriculture, Forestry and Other Land Use (AFOLU) Sector for Mauritius

- In the Republic of Mauritius, most of the GHG emissions/removals from AFOLU sector are generated by Forestland (which is a key category), Enteric Fermentation, Manure Management, Agricultural Soils and Field Burning.
- In the AFOLU sector, there is more carbon sequestered than emitted.
- Forests are the largest component of this sector, acting as net carbon sinks



Methodologies Applied in Previous GHG Inventories for AFOLU Sector

A combination Tier I (T1) and Tier 2 (T2) have been used to calculate the emissions/removals in the AFOLU sector. While most of the AD has been obtained locally, the EFs have mainly been drawn from the 2006 IPCC guidelines and hence are default values with country specific adjustment:

- For enteric fermentation and manure management, the combined Tier I and Tier 2 were applied for emissions estimation;
- For aggregate sources and non-CO_2 emissions sources on land, the combined Tier I and Tier 2 were applied for emissions estimation;
- For Forest Land, mostly Tier I was applied for emissions estimation; and
- For Cropland, the Tier I was applied for emissions estimation.

ALU National GHG Inventory Software

Why was the ALU Software Developed?

- Agriculture and Land Use Greenhouse Gas Inventory Software (ALU) was developed based on experiences in EPA led capacity building projects
- Spreadsheets provide basic functionality for an inventory
- ALU was envisioned to provide advanced functionality beyond that available in spreadsheets
  - Guide the compiler through the process of the inventory analysis for LULUCF and Agriculture
  - Provide data management capabilities
  - Provide utilities that encourage good practice
    - e.g., application of Tier 2 methods
  - Prevent obvious errors in the inventory analysis

ALU National GHG Inventory Software

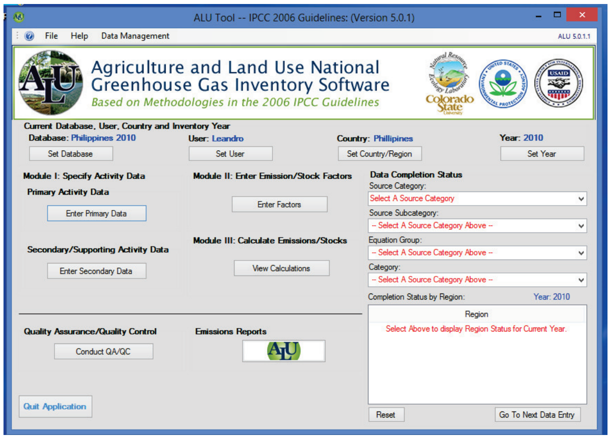
Comparison of Software Packages

	IPCC 2006 GL Software	ALU Software
Guidelines	2006 IPCC Guidelines	GPG 2000, GPG 2003 for LULUCF 2006 IPCC Guidelines
Sectors	All sectors	Agriculture and LULUCF/AFOLU
Tier Method	Tier 1	Tier 1 and 2
Uncertainty Analysis	Yes	Yes
User-defined stratification (e.g., climate types)	Yes	Yes
QA/QC Functions	No	Yes
Documentation Capability for Data Sources	No	Yes
Import GIS/Remote Sensing Data	No	Yes
Key Category Analysis	Yes	No (need all sectors)
GHG Mitigation Analysis	No	Yes

ALU Software Publication: Ogle, S.M., S. Spencer, M. Hartman, L. Buendia, L. Stevens, L. Du Toit, J. Witi. 2015. Developing national baseline GHG emissions and analyzing mitigation potentials for Agriculture and Forestry using an advanced national GHG inventory software system. In Synthesis and Modeling of Greenhouse Gas Fluxes and Carbon Changes in Agricultural and Forest Systems to Guide Mitigation and Adaptation, eds. S.Del Grosso, W. Parton and L. Ahuja. ACSESS Books, ASA-SSSA-CSSA, Madison, Wisconsin, USA, DOI:10.2134/advagricsystmodel6.2013.0009.

ALU Greenhouse Gas Inventory Software

➢ **How can the Agriculture and Land Use (ALU) software assist greenhouse gas inventory compilers in Mauritius?**



IPCC Good Practice

Transparency	• Data sources, assumptions and methodologies are clearly explained and documented to facilitate replication and assessment
Accuracy	• Estimates are neither systematically over nor under as far as can be judged; uncertainties are reduced as far as practicable
Consistency	• Estimates are calculated using same methodologies and same sources of data for base year and subsequent years to reflect real fluctuations in emission/ removal over the time series; not subject to changes resulting from methodological change.
Comparability	• Methodologies and formats are comparable as agreed by COPs; source/sink categories are based on the IPCC Guidelines
Completeness	• All IPCC source/sink categories are included, as well as gases (to extent methods are provided) and full geographic coverage of sources/sinks categories

Transparency

Good Practice: Documentation and Archiving

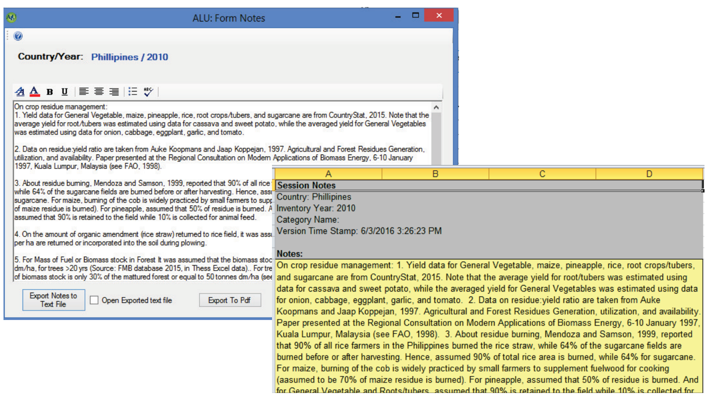
- It is good practice to be transparent by documenting methods
- Why? So that other parties understand how the estimates were derived
- Also, institutional memory requires documentation and archiving
- ALU has utilities to facilitate documentation and make archiving easy for the compiler

Transparency

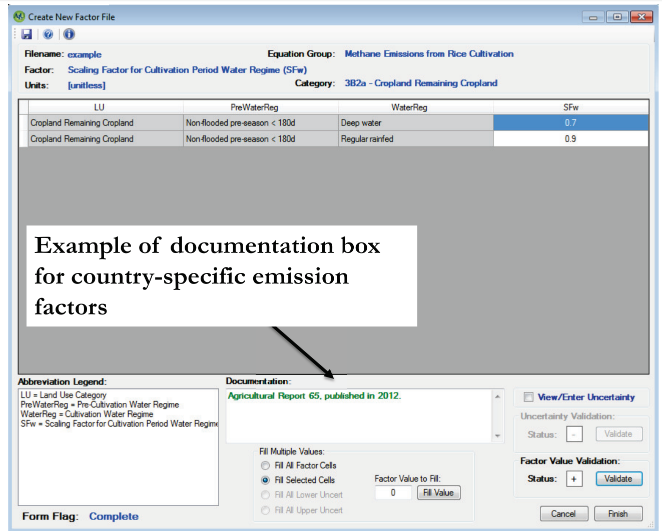
➢ **ALU 2006 organizes activity data and assigns emission/stock factors in a transparent and efficient manner …**

Transparency

- Activity data sources and assumptions are documented (using Form Notes) and exported in Excel file for reference and review …

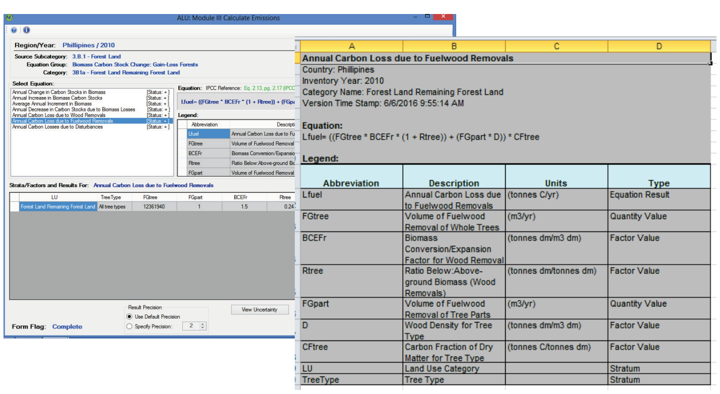


Transparency



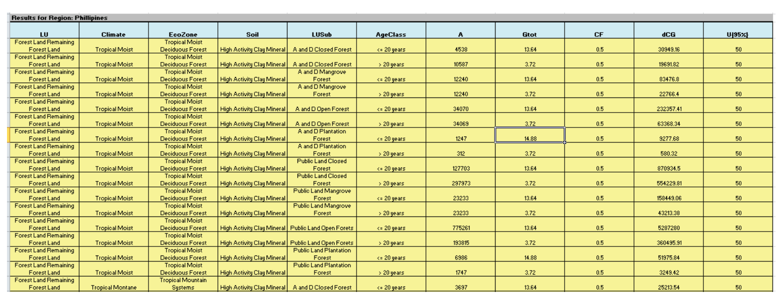
Transparency

- Equations are shown during the process for checking and validation, and are exported in Excel file for reference …



Transparency

- All activity data, emission factors, and GHG estimates are reported in Excel file for exchange, review, and analysis.



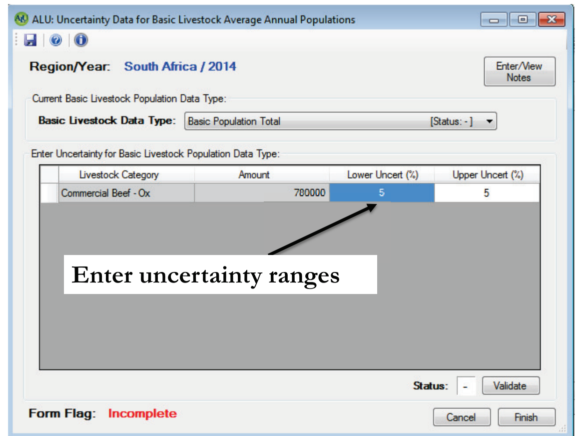
Example of Activity Data, Emission Factors, and Estimates for Annual Increase in Biomass Carbon Stock in Forest Land

Accuracy

Quantify and Reduce Uncertainty

- Inventories following good practice "contain neither over- nor under-estimates so far as can be judged, and which uncertainties are reduced as far as is practicable" (IPCC GPG 2000).
- Difficult to evaluate if uncertainty is not estimated
- Moreover, uncertainty is sometimes an after-thought for compilers
- ALU encourages the compilation of data that is necessary to estimate uncertainty associated with activity data and emission factors

Accuracy



Accuracy

Combining Uncertainties with Multiplication:

EQUATION 3.1
COMBINING UNCERTAINTIES – APPROACH 1 – MULTIPLICATION

$$U_{total} = \sqrt{U_1^2 + U_2^2 + \ldots + U_n^2}$$

Where:

U_{total} = the percentage uncertainty in the product of the quantities (half the 95 percent confidence interval divided by the total and expressed as a percentage);

U_i = the percentage uncertainties associated with each of the quantities.

Combining Uncertainties with Addition and Subtraction:

EQUATION 3.2
COMBINING UNCERTAINTIES – APPROACH 1 – ADDITION AND SUBTRACTION

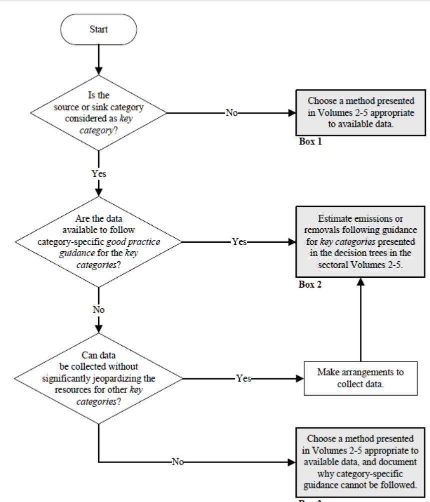
$$U_{total} = \frac{\sqrt{(U_1 \bullet x_1)^2 + (U_2 \bullet x_2)^2 + \ldots + (U_n \bullet x_n)^2}}{|x_1 + x_2 + \ldots + x_n|}$$

Where:

U_{total} = the percentage uncertainty in the sum of the quantities (half the 95 percent confidence interval divided by the total (i.e., mean) and expressed as a percentage). This term 'uncertainty' is thus based upon the 95 percent confidence interval;

x_i and U_i = the uncertain quantities and the percentage uncertainties associated with them, respectively.

Accuracy



IPCC Methods

Methodological Tiers

- Different levels of complexity and integration of country-specific information

Accuracy ↓ **Precision** ↓ **Complexity** ↓

IPCC Tiers	Estimation method	Coefficients	Activity data detail
Tier 1	Empirical	Default	Low
Tier 2	Empirical/ Simulated	Country-specific	Medium
Tier 3	Simulation/ measured inventory	Country-specific	High

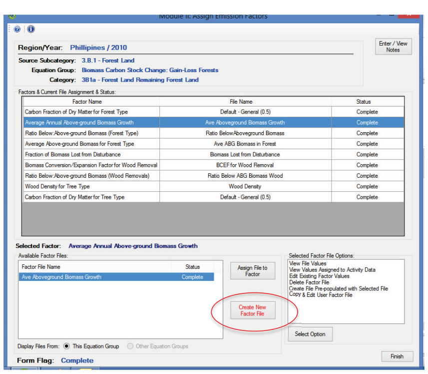
Accuracy

Advance to Higher Tiers

- Tier 1 is acceptable for reporting but default emission factors can lead to significant biases
- It is good practice to apply Tier 2 or 3 for key sources
- Why? Provides more accurate emission estimates
- In addition, there are limited strata for assigning Tier 2 factors in spreadsheets
- ALU facilitates application of Tier 2 methods from activity data compilation to assignment of emission factors.

Accuracy

- **Allows the use of Tier 2 methods (by disaggregating categories) in order to reduce uncertainty and improve GHG estimates; assigning of country-specific emission factors**



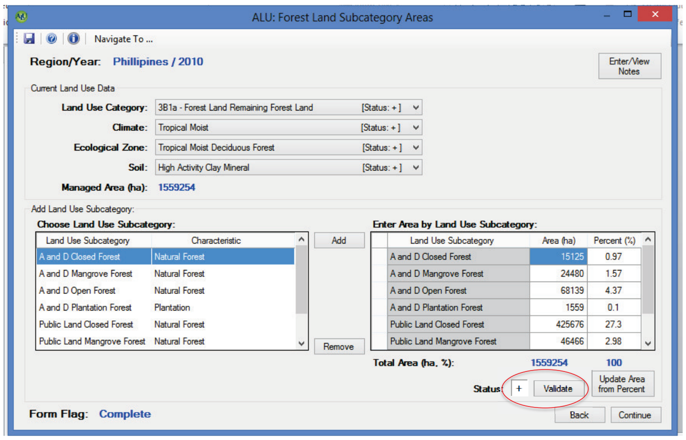
Accuracy

Quality Assurance/Quality Control

- It is good practice to conduct QA/QC
- Why? Reviewing the data uncovers errors by compilers. Also can allow input of third parties who may have knowledge of other data relevant for the inventory
- ALU provide a utility that facilitates QA/QC
  - Interface displays data which can be validated as QA/QC is completed
  - Export QA/QC data for ease of distribution for review

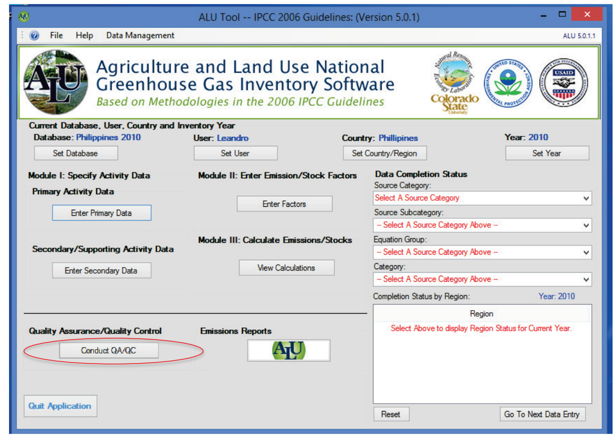
Accuracy

➢ **Always ask to "Validate" the data to ensure that entries are correct**

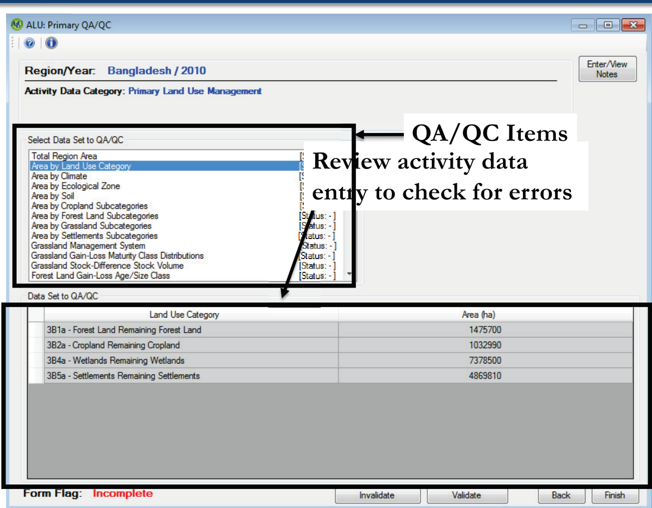


Accuracy

➢ **Allows to conduct "QA/QC" before having any final calculation and reporting …**



Accuracy



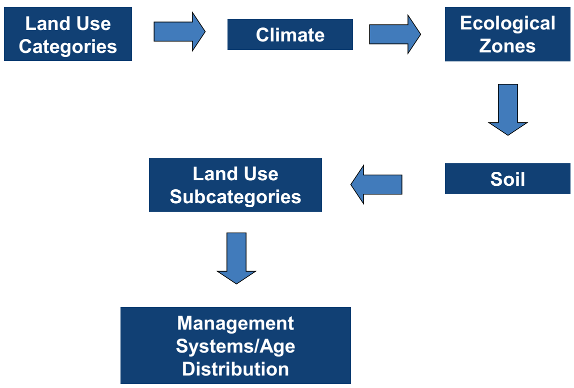
Consistency

Consistent Application of Methods

- It is good practice to have a consistent application of methods across the inventory time series
- Why? Because evaluating trends in emissions is a goal of an inventory so that it is possible to determine if emissions are increasing or decreasing
- ALU facilitates recalculation and consistent application of methods across a time series

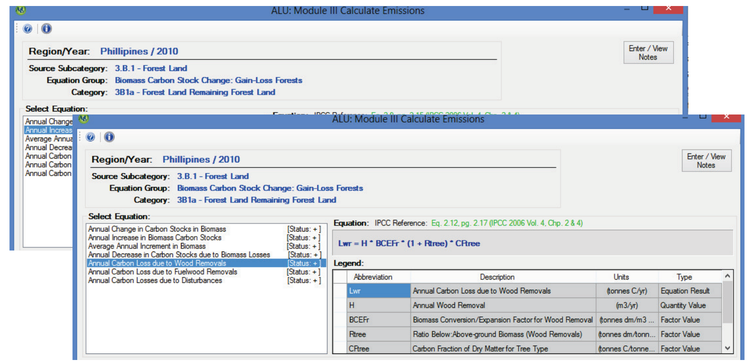
Consistency

- **Enables consistent representation of land use and livestock population**
  - ✓ provides method for building consistency in the inventory across space and time….



Comparability

- **All methods are based on the IPCC Guidelines which will lead to an inventory that is comparable to other countries.**



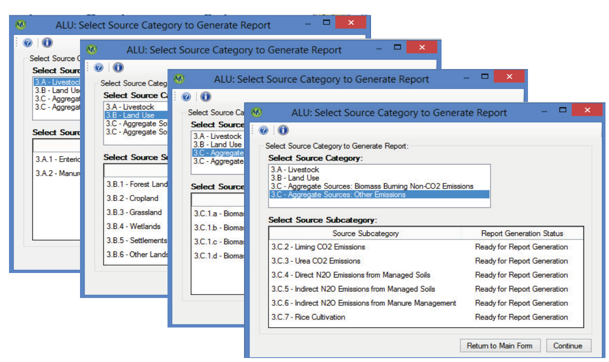
Completeness

Complete Inventory

- It is good practice to include all sources of anthropogenic emissions.
- Why? Because missing sources can lead to biases in emission estimates and results may not be comparable to other countries
- To meet this goal for AFOLU, it is good practice to estimate emissions for all sources in the sector.
- In addition, for land management, it is important to classify the entire national land base into managed/unmanaged land and apply the IPCC land use classification
- Why? Allows for a full accounting of all emissions from managed land in a manner comparable to other countries.
- ALU facilitates use of remote sensing-based products to achieve a complete representation of managed land base across the time series

Completeness

- **ALL sources and sink categories are covered in ALU …**

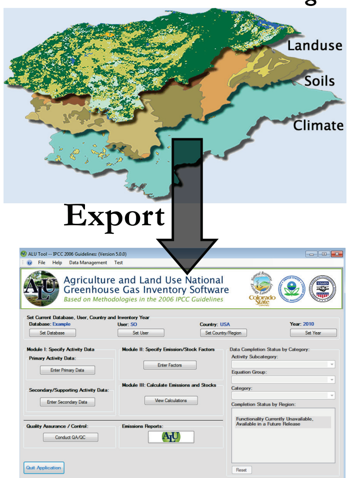


Note: With the exception of HWP, peat extraction and dead organic matter are assumed to not be changing (i.e., Tier 1 assumption).

Completeness

Utilize Spatial Data and Remote Sensing Products

(Geographic Information System)



ALU allows import of data from a GIS file

Data Management

Other Functions: Data Management

- The AFOLU sector requires considerable data
- Relational database structure
  - Efficient storage of data
  - Difficult to develop without database experience
- ALU relates activity data directly to calculations
- ALU assigns emission factors automatically

GHG Mitigation

Other Functions: Mitigation Analysis

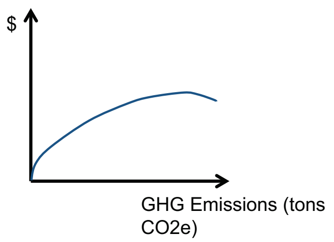
- Inventories should form the basis to consider mitigation options and monitor outcomes of policy actions intended to reduce emissions
- With an inventory developed using good practices, compilers can be confident in assessing mitigation potentials with robust estimates of baseline emissions
- Evaluating mitigation potentials can involve a variety of drivers including technological change, population growth, and economic growth
- ALU facilitates mitigation analysis using the inventory developed with good practice for the baseline
  - Functionality to be released in 2017 for the 2006 GL Version of the ALU software

Technical GHG Mitigation Potentials

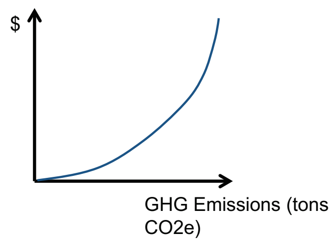
- Technical potential is the amount by which it is possible to pursue a specific objective through an increase in deployment of technologies or implementation of processes and practices that were not previously used or implemented (IPCC Fifth Assessment Report, WG III)
- Quantification of may take into account social, economic and or environmental consideration.
  - Economic – costs and returns from changing practices
  - Social – barriers due to cultural and practical concerns
  - Environmental – other impacts of changing practices on the environment

Economic Example
Benefit and Cost of Emissions – Global

1. Benefit of emitting to society



2. Cost of emitting due to climate change



Benefits and Costs—Abatement

Abatement Benefits

- Reduced climate change and less impact on future generations
- Decreased costs associated with adaptation to climate change
- Meeting commitments in national and international agreements

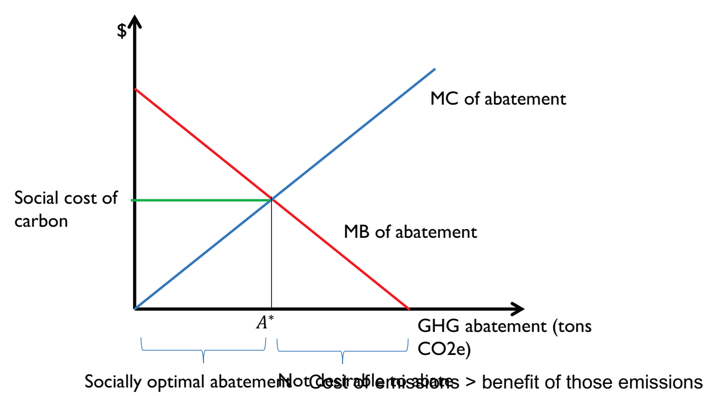
Abatement Costs

- Giving up the benefit of emissions if there are not viable alternatives
- Potentially higher consumer prices/lower producer earnings

Marginal Benefit and Cost of Abatement

- Marginal cost of abatement: cost of reducing the *last* unit of emissions (ton of CO_2e)
  - e.g., reduction in net earnings by adopting an additional low-emitting technology
- Marginal benefit of abatement: benefit of reducing the last unit of emissions
  - e.g., less climate change

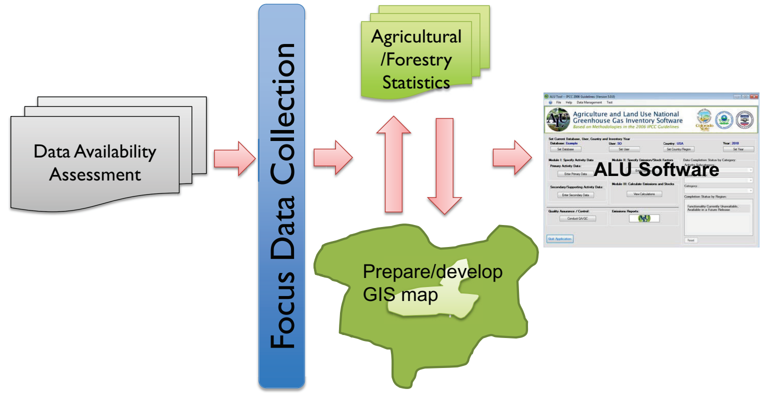
Marginal Benefit and Cost of Abatement – Global



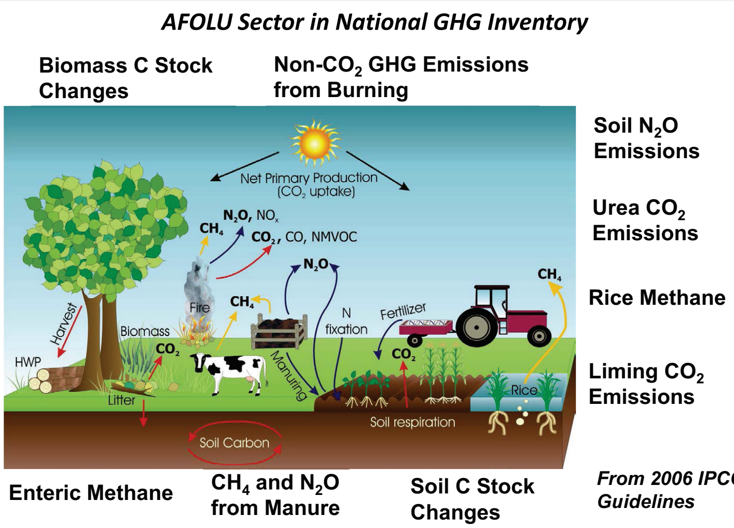
GHG Mitigation

- Projecting business as usual and technical emission reductions in ALU after determining the level of abatement that is desirable and feasible given costs, social and other environmental impacts of GHG emission reductions

ALU National GHG Inventory Software



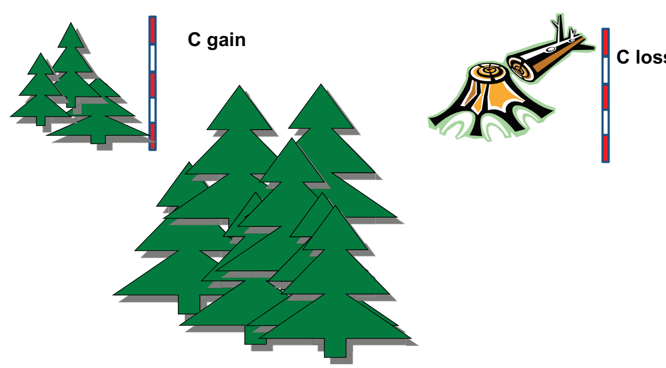
ALU National GHG Inventory Software



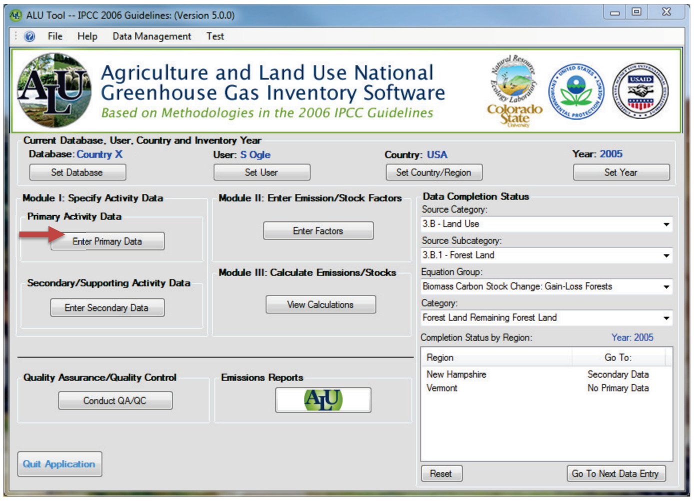
From 2006 IPCC Guidelines

ALU National GHG Inventory Software

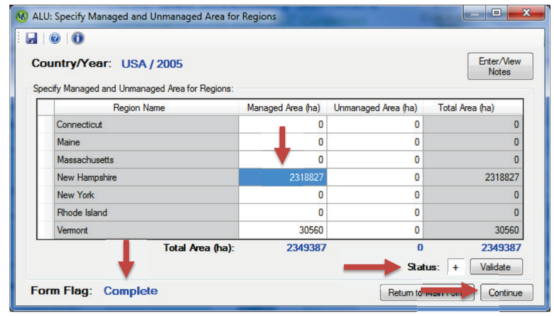
Case Example: Gain-Loss Method



ALU National GHG Inventory Software



ALU National GHG Inventory Software



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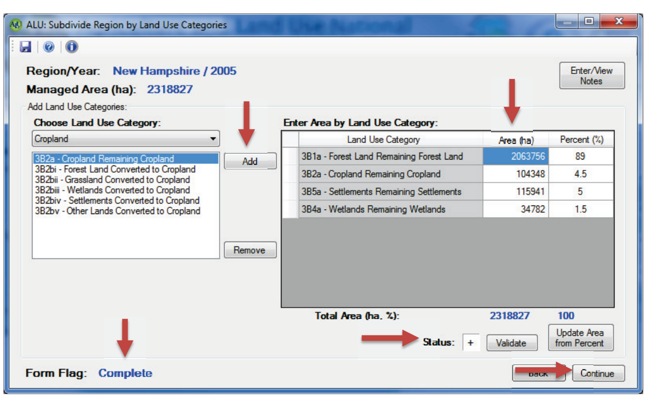

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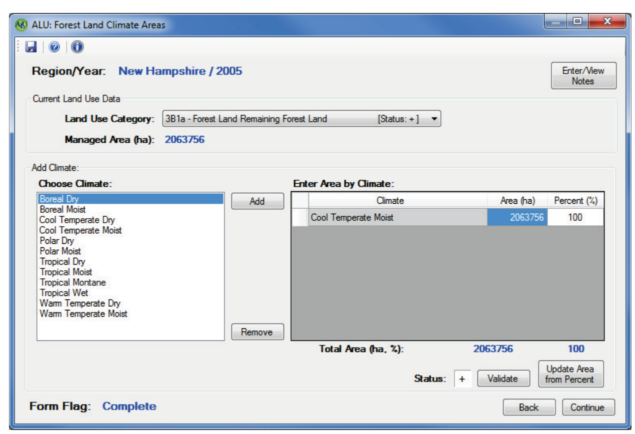

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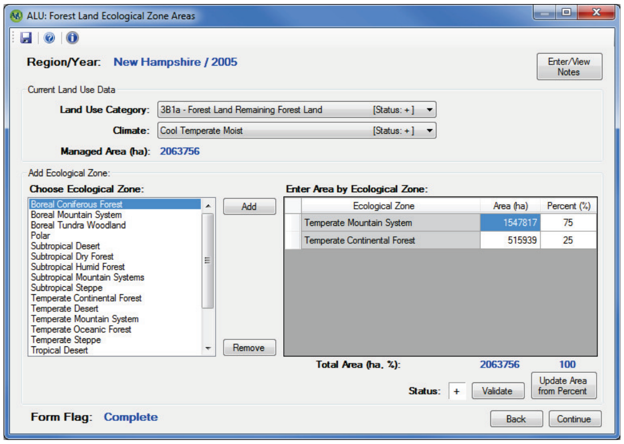

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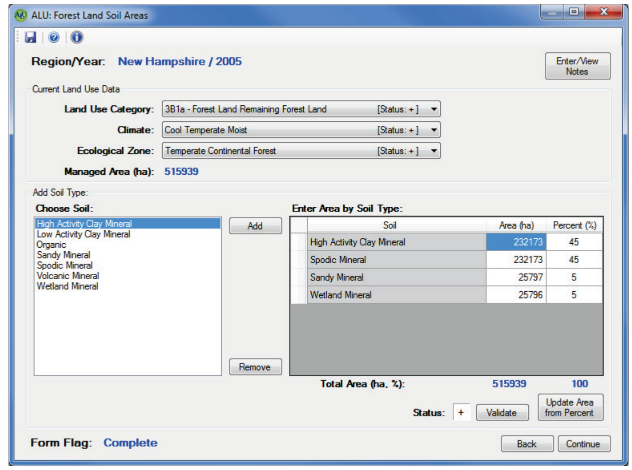

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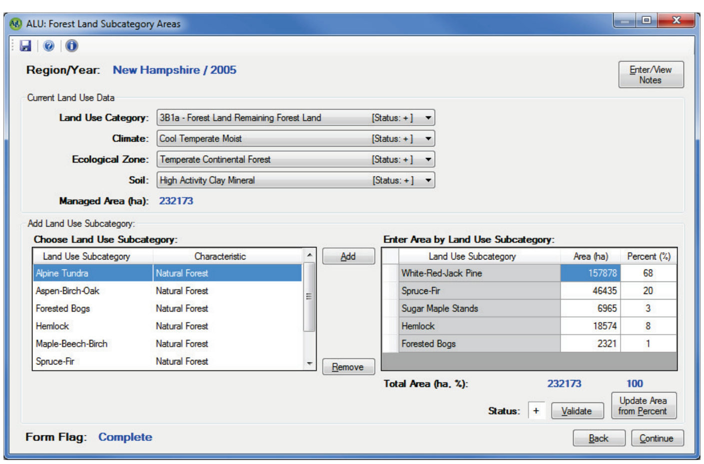

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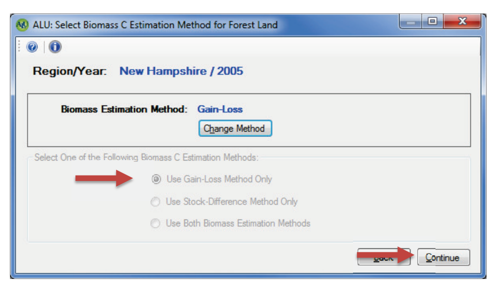

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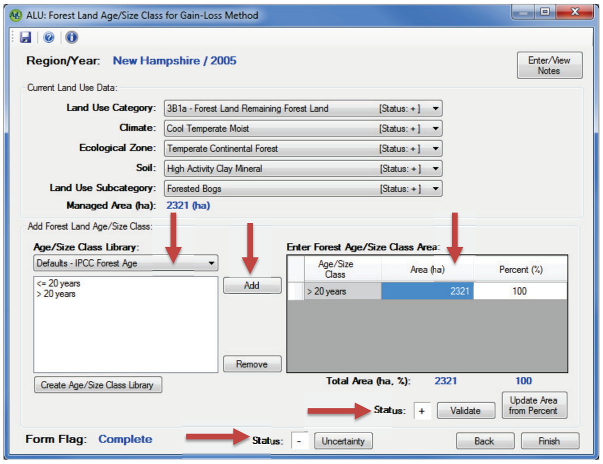

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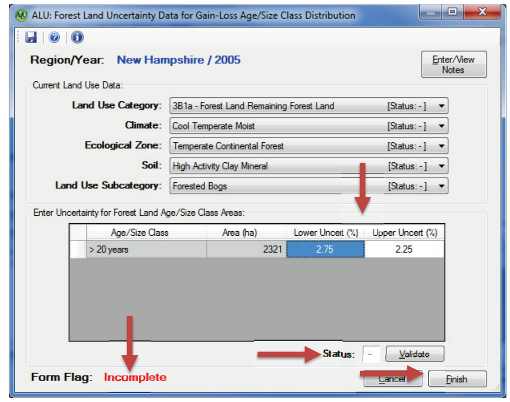

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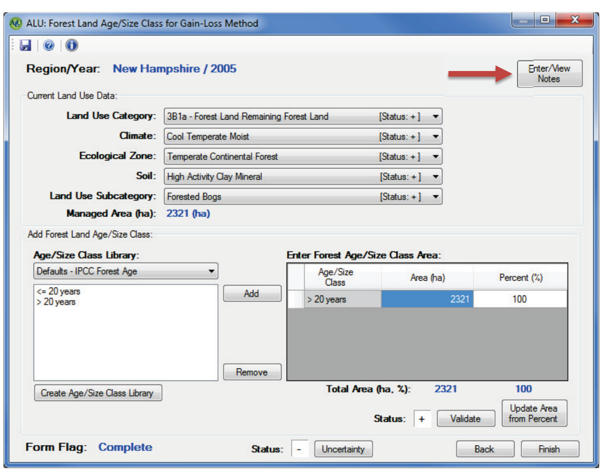

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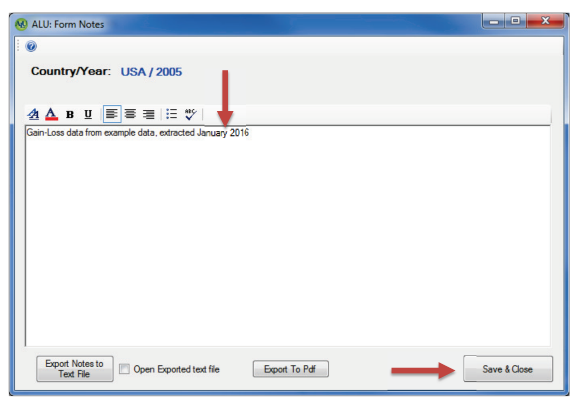

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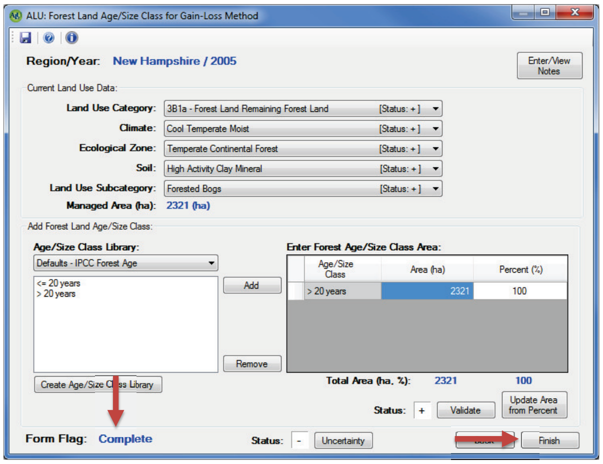

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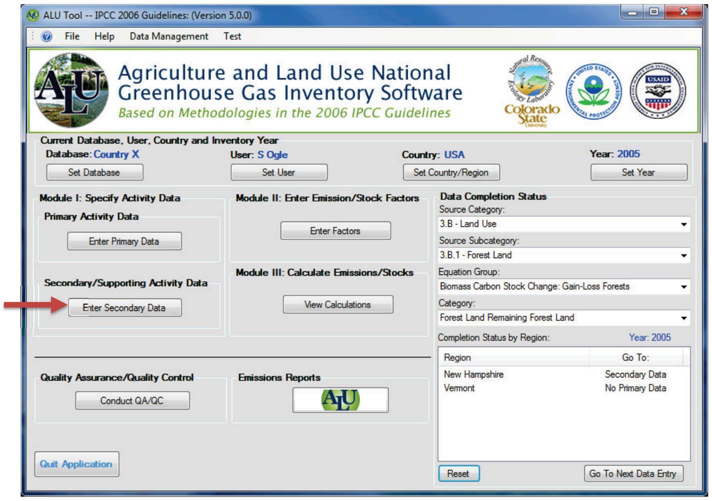

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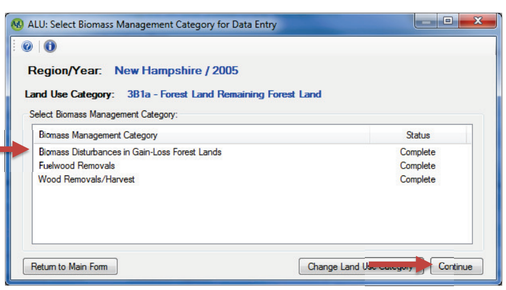

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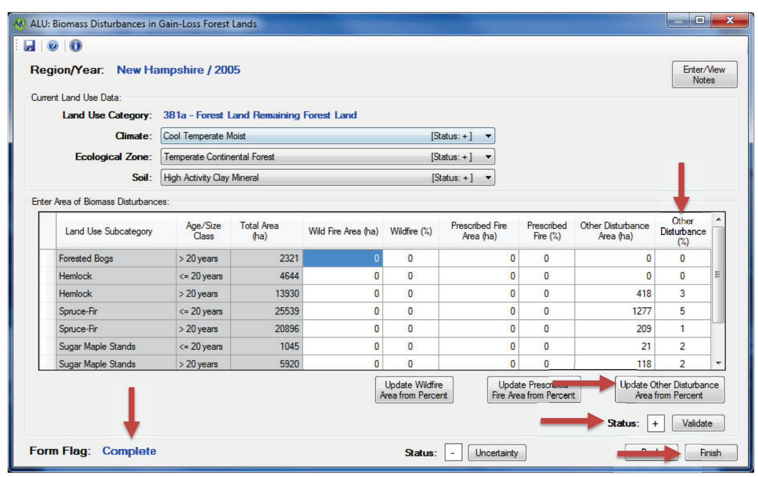

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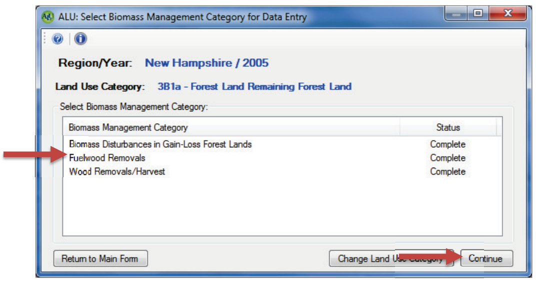

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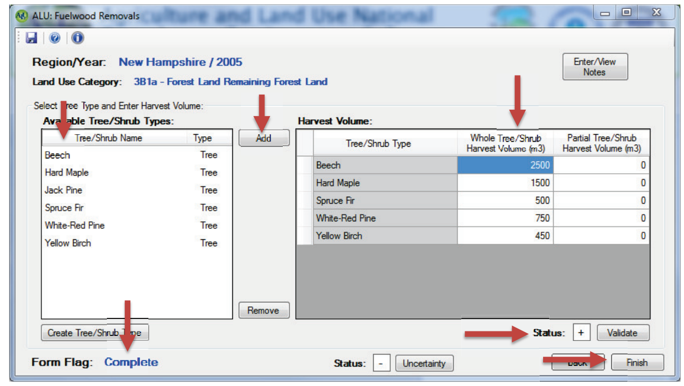

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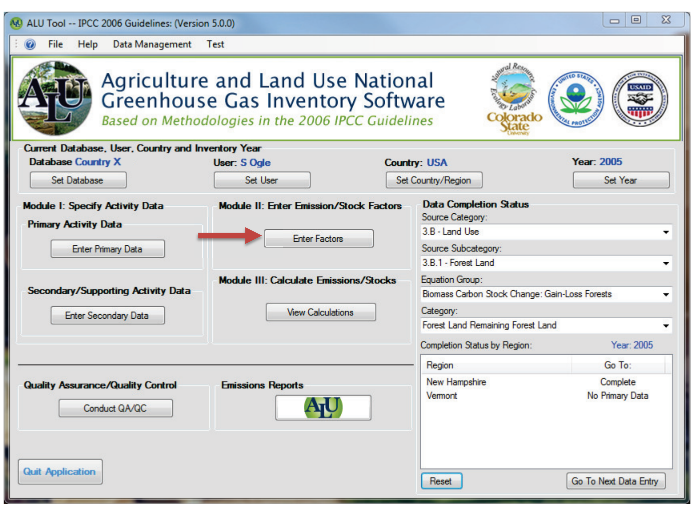

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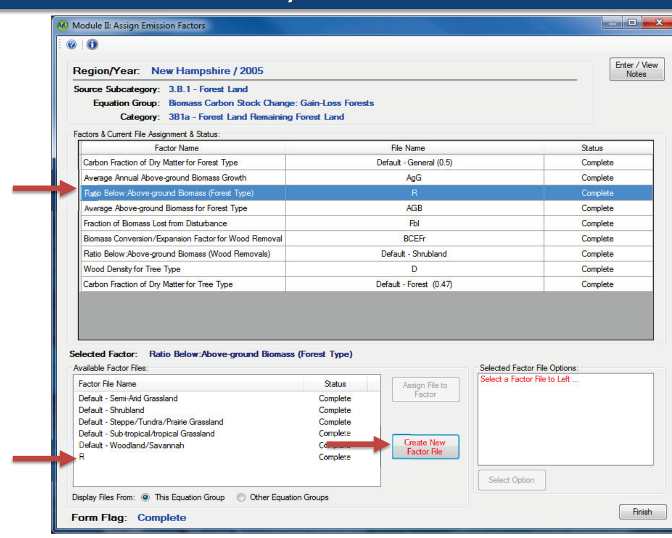

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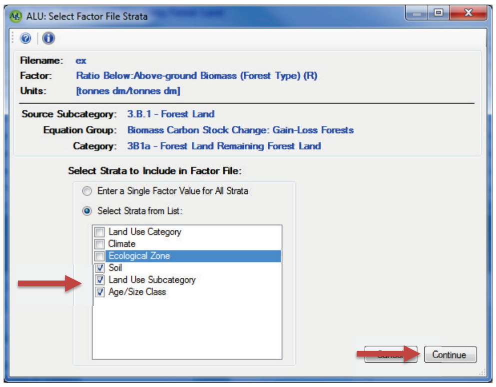

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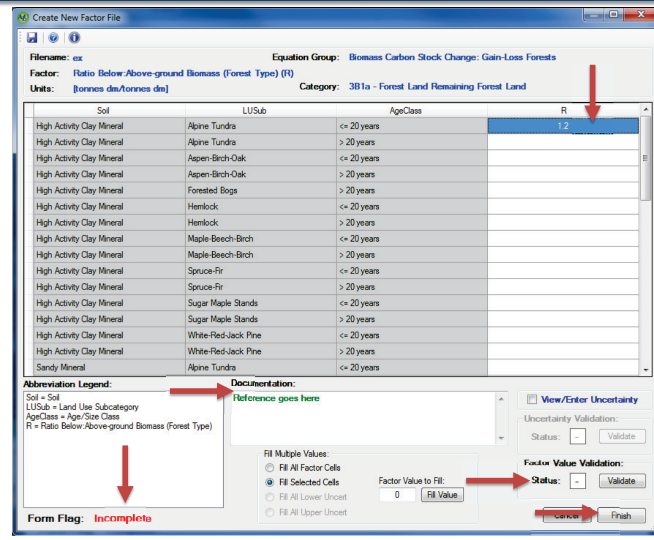
ALU National GHG Inventory Software



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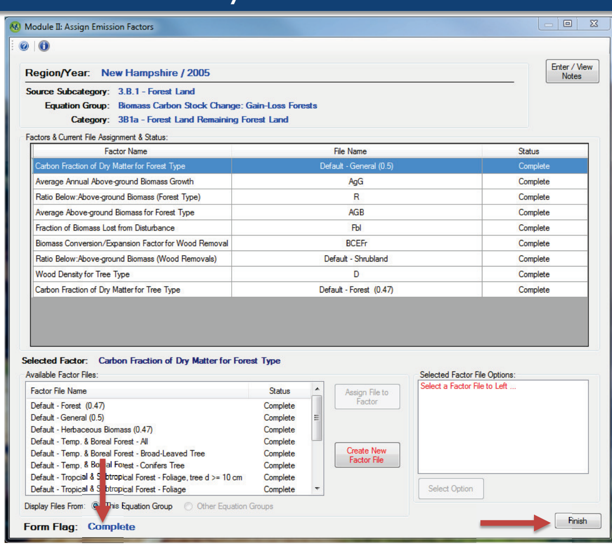

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ALU National GHG Inventory Software

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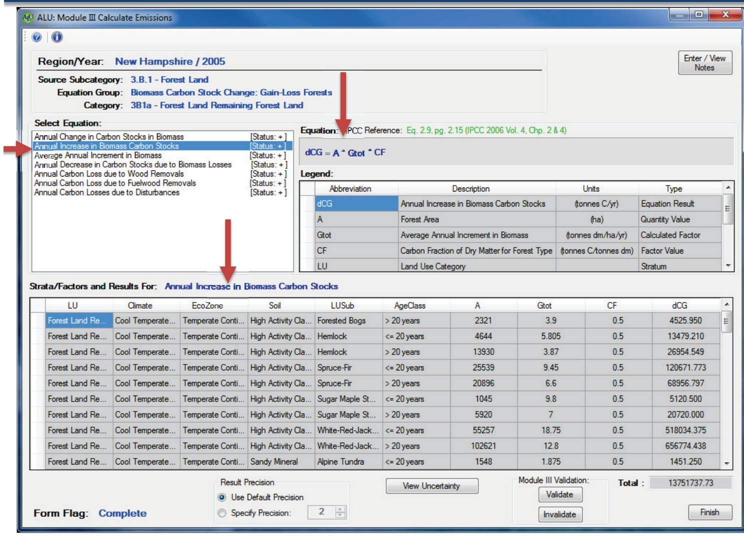
ALU National GHG Inventory Software



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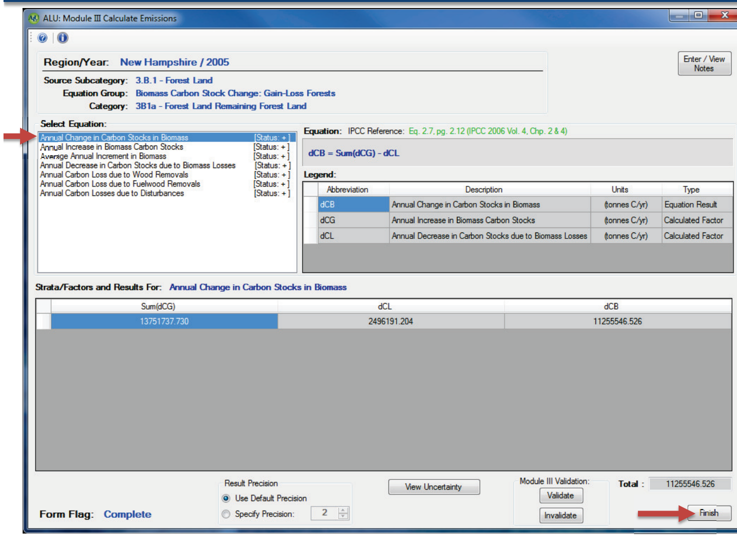
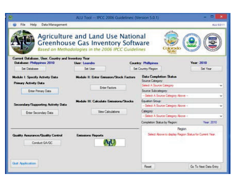


Summary

ALU 2006 Software:



- ✓ Is a free tool to implement/apply the IPCC Revised 1996 Guidelines with GPG 2000 and 2003, or the IPCC 2006 Guidelines
- ✓ Guides the user to compile a transparent, accurate, consistent, complete and comparable AFOLU sector GHG Inventory
- ✓ Helps to manage and integrate data, including linkages with other tools
- ✓ Supports improvement and continuity over time (e.g., moving to Tier 2, and with database functionalities)
- ✓ Is also a mitigation analysis tool for developing emission/removal projections and assessing potential mitigation options in AFOLU categories

Overall, ALU provides utilities that encourage the use of "good practice" in compiling a GHG emissions inventory.

Contact Information

Thanks For Your Attention!

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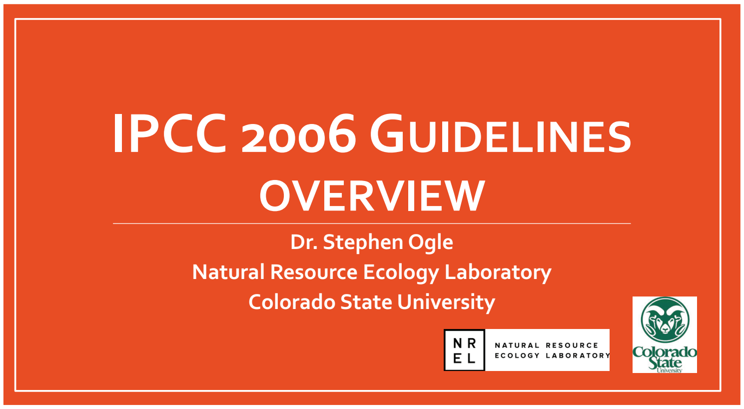
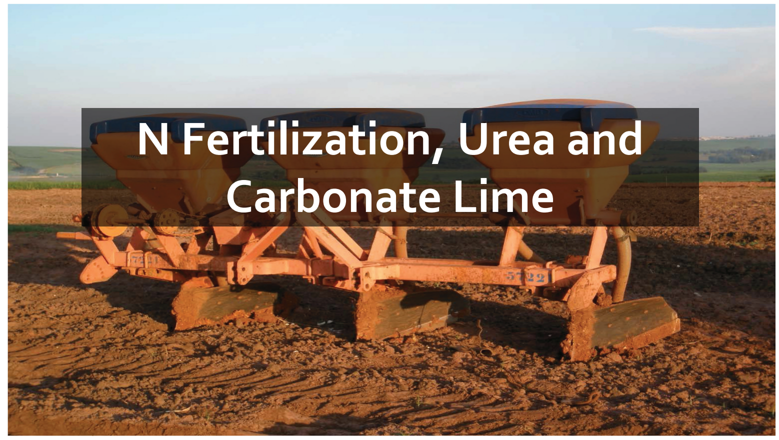
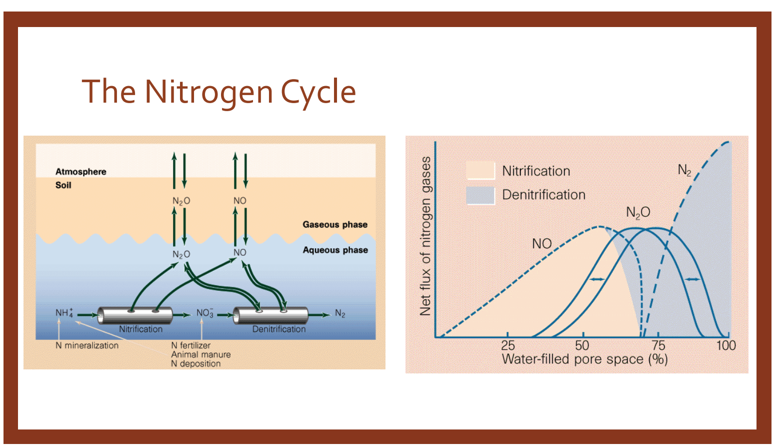
Colorado State University
Email: stephen.ogle@colostate.edu

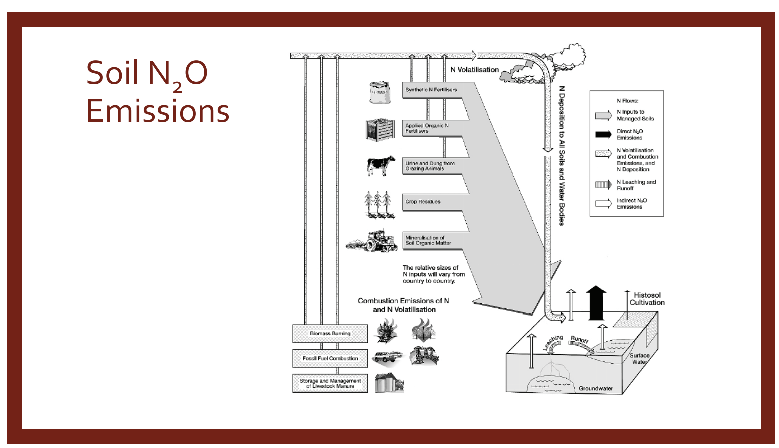
ALU Software
www.nrel.colostate.edu/projects/ghgtool

Annex V: Presentation on Overview 2006 IPCC Guidelines AFOLU Sector

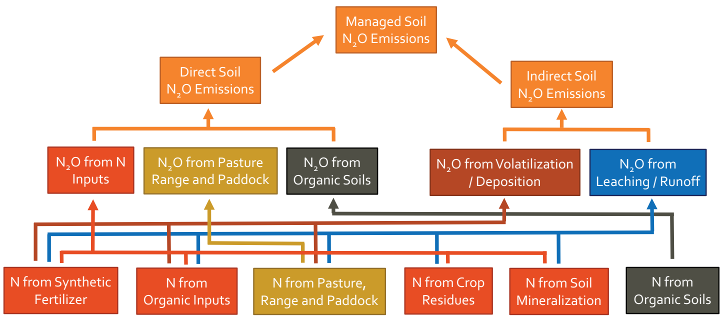








N_2O Emissions from Managed Soils



Direct Soil N_2O Emissions

Equation:

$$N_2O_{Direct} = N_2O_{NI} + N_2O_{OS} + N_2O_{PRP} \qquad \text{(eq. 11.1)}$$

Parameters:

N_2O_{Direct}	= Annual direct N_2O-N emissions from managed soils	(kg N_2O-N year^{-1})
N_2O_{NI}	= Annual direct N_2O-N emissions from N inputs to managed soils	(kg N_2O-N year^{-1})
N_2O_{OS}	= Annual direct N_2O-N emissions from managed organic soils	(kg N_2O-N year^{-1})
N_2O_{PRP}	= Annual direct N_2O-N emissions from urine and dung inputs to grazed soils	(kg N_2O-N year^{-1})

(2006 IPCC Guidelines, Vol 4 Ch 11; eq 11.1; pg 11.7)

Soil N_2O Emissions from N Inputs

Equation:

$$O_{NI} = (F_{SN} + F_{ON} + F_{CR} + F_{SOM}) \times EF_1 \qquad \text{(eq. 11.1)}$$

Parameters:

N_2O_{NI}	**= Annual direct N_2O-N emissions from N inputs to managed soils**	**(kg N_2O-N year^{-1})**
F_{SN}	**= Annual amount of synthetic fertilizer N applied to soils**	**(kg N year^{-1})**
F_{ON}	**= Annual amount of animal manure, compost, sewage sludge and other organic N applied to soils**	**(kg N year^{-1})**
F_{CR}	**= Annual amount of N in crop residues applied to soils**	**(kg N year^{-1})**
F_{SOM}	**= Annual amount of N in mineral soils that is mineralized due to land use change or management**	**(kg N year^{-1})**
EF_1	**= Emission factor for N_2O-N emissions from N inputs**	**(kg N_2O-N (kg N input)$^{-1}$)**

(2006 IPCC Guidelines, Vol 4 Ch 11; eq 11.1, 11.2; pg 11.7-8)

Indirect N_2O from Volatilization / Deposition

Equation:

$$N_2O_{VD} = \left[\left(F_{SN} \times f_{vol_s} \right) + \left(\left(F_{ON} + F_{PRP} \right) \times f_{vol_o} \right) \right] \times EF_4 \qquad \text{(eq. 11.9)}$$

Parameters:

N_2O_{VD}	= Annual indirect N_2O-N emissions from deposition of volatilized N	(kg N_2O-N year^{-1})
F_{SN}	= Annual amount of synthetic fertilizer N applied to soils	(kg N year^{-1})
$f_{vol_{s,o}}$	= Fraction of synthetic fertilizers (s) or organic inputs (o) that volatilize as NH_3 and NO_x	(fraction)
F_{ON}	= Annual amount of animal manure compost sewage sludge and other organic N applied to soils	(kg N year^{-1})
F_{PRP}	= Annual amount of urine and dung N deposited on pasture, range and paddock	(kg N year^{-1})
EF_4	= Emission factor for N_2O emissions from deposition of volatilized N	(kg N_2O-N (kg N)$^{-1}$)

(2006 IPCC Guidelines, Vol 4 Ch 11; eq 11.9; pg 11.21)

Indirect N_2O from Leaching / Runoff

Equation:

$$N_2O_{LR} = (F_{SN} + F_{ON} + F_{PRP} + F_{CR} + F_{SOM}) \times f_{lr} \times EF_5$$ (eq. 11.10)

Parameters:

N_2O_{LR}	= Annual indirect N_2O-N emissions from leaching and runoff of N	(kg N_2O-N year^{-1})
F_{SN}	= Annual amount of synthetic fertilizer N applied to soils	(kg N year^{-1})
F_{ON}	= Annual amount of animal manure compost sewage sludge and other organic N applied to soils	(kg N year^{-1})
F_{PRP}	= Annual amount of urine and dung N deposited on pasture, range and paddock	(kg N year^{-1})
F_{CR}	= Annual amount of N in crop residues applied to soils	(kg N year^{-1})
F_{SOM}	= Annual amount of N in mineral soils that is mineralized due to land use change or management	(kg N year^{-1})
f_{lr}	= Fraction of N lost to leaching and runoff	(fraction)
EF_5	= Emission factor for N_2O emissions from leaching and runoff of N	(kg N_2O-N (kg N)$^{-1}$)

(2006 IPCC Guidelines, Vol 4 Ch 11; eq 11.10; pg 11.21)

CO_2 from Urea Fertilization

Equation:

$$CO_{2U} = M_u \times EF_u$$ (eq. 11.13)

Parameters:

$CO2_U$	= Annual CO2-C emissions from urea fertilization	(tonnes C year^{-1})
M_u	= Annual amount of urea	(tonnes)
EF_u	= Emission factor for urea (IPCC default = 0.20)	(tonnes C (tonnes urea)$^{-1}$)

(2006 IPCC Guidelines, Vol 4 Ch 11; eq 11.13; pg 11.32)

Soil Liming

- Made from carbonate rock ($CaCO_3$ or $CaMg(CO_3)_2$) , a long term sink for CO_2
- Used to buffer pH by the Ca and Mg provided
- Liming agents include limestone, dolomite, marl and chalk

CO_2 from Liming

Equation:

$$CO_{2L} = (M_l \times EF_l) + (M_d \times EF_d)$$ (eq. 11.12)

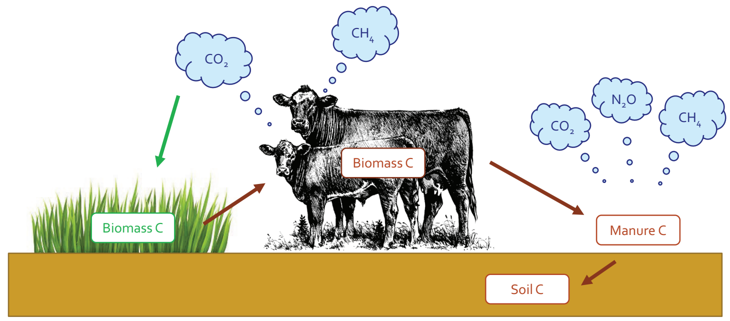
Parameters:

$CO2_L$	= Annual CO2-C emissions from lime application	(tonnes C year^{-1})
M_l	= Annual amount of calcic limestone	(tonnes)
EF_l	= Emission factor for calcic limestone	(tonnes C (tonnes limestone)$^{-1}$)
M_d	= Annual amount of dolomite	(tonnes)
EF_d	= Emission factor for dolomite	(tonnes C (tonnes dolomite)$^{-1}$)

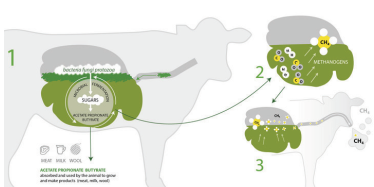
(2006 IPCC Guidelines, Vol 4 Ch 11; eq 11.12; pg 11.27)

Livestock & Manure Management

GHGs from Livestock / Manure



Enteric Fermentation



- Microbes that aid in digestive processes in the rumen produce CH_4
- CH_4 production will depend on feed intake and quality, livestock breed, animal age, animal energy expenditure and environmental factors

Basic Livestock Characterization

Equation:

$$AAP_l = \frac{DA_l}{365} \times NAPA_l \quad \text{(eq. 10.1)}$$

Parameters:

AAP_l = Average annual population for livestock category l (head year^{-1})

DA_l = Average days alive from livestock category l (days)

$NAPA_l$ = Number of animals produced annually from livestock category l (head year^{-1})

(2006 IPCC Guidelines, Vol 4, Ch 10; eq 10.1; pg 10.8)

Tier 2 Enhanced Characterization

Enhanced characterization data

- Average annual population
- Average daily feed intake
- CH_4 conversion factors

Data to estimate feed intake

- Weight
- Average weight gain per day
- Feeding situation (confined, grazing, pasture)
- Milk production per day and fat content
- Average work performed per day
- Percentage females that give birth
- Number of offspring
- Wool growth
- Feed digestibility

Tier 2 Enteric CH_4 Emission Factor

Tier 2 Equation:

$$EF_{EM_l} = \frac{GE_l \times \frac{Ym_l}{100} \times 365}{55.65}$$ (eq. 10.21)

Parameters:

EF_{EM_l}	Enteric CH_4 emission factor for livestock category l	(kg CH_4 head^{-1} year^{-1})
GE_l	Gross energy intake for livestock category l	(MJ head^{-1} day^{-1})
Y_{m_l}	CH_4 conversion factor, percent of gross energy in feed converted to CH_4 livestock category l	(percentage)
55.65	Energy content of methane	(MJ (kg CH_4)$^{-1}$)

(2006 IPCC Guidelines, Vol 4 Ch 10, 10.21 ; pg 10.28-31)

Enteric CH_4 Methods

Tier 1 Equation:

$$CH_{4_{EM}} = \sum_{l=1}^{L} \frac{EF_{EM} \times AAP_l}{1{,}000{,}000}$$ (eq. 10.19)

Parameters:

CH_{4EM}	CH_4 emissions from enteric fermentation	(Gg CH_4 year^{-1})
EF_{EM_l}	Enteric CH_4 emission factor for livestock category l	(kg CH_4 head^{-1} year^{-1})
AAP_l	Average annual population in livestock category l	(head)

(2006 IPCC Guidelines, Vol 4 Ch 10; Table 10.12; pg 10.30)

Manure Management CH_4

Tier 1 Equation:

$$CH_{4_{MM}} = \sum_{l=1}^{L} \frac{EF_{MM_l} \times AAP_l}{1{,}000{,}000}$$

Tier 2 Equation:

$$EF_{MM_l} = (VS_l \times DA_l \times MM_l \times 0.67) \times \sum_{s=1}^{S} \sum_{t=1}^{T} \left(\frac{MCF_{s,t}}{100} \times MS_{l,s,t} \right)$$

Parameters:

EF_{MM_l}	= Annual manure CH_4 emission factor for livestock category l	(kg CH_4 head^{-1} year^{-1})
AAP_l	= Average annual population in livestock category l	(head)
VS_l	= Daily volatile solid excreted for livestock category l	(kg dry matter head^{-1} day^{-1})
DA_l	= Annual days alive for livestock category l	(days year^{-1})
MM_l	= Maximum CH_4 producing capacity for livestock category l	(m^3 CH_4 (kg dry matter)$^{-1}$)
$MCF_{s,t}$	= CH_4 conversion factor for manure management system s, at temperature t	(kg N_2O-N (kg N)$^{-1}$)
$MS_{l,s,t}$	= Fraction of livestock category l's manure in management system s at temperature t	(fraction)
0.67	= Conversion factor from m^3 CH_4 to kg CH_4	

(2006 IPCC Guidelines, Vol 4 Ch 10; eq 10.22, 10.23; pg 10.37, 10.41)

Volatile Solid Excretion Rate

Equation:

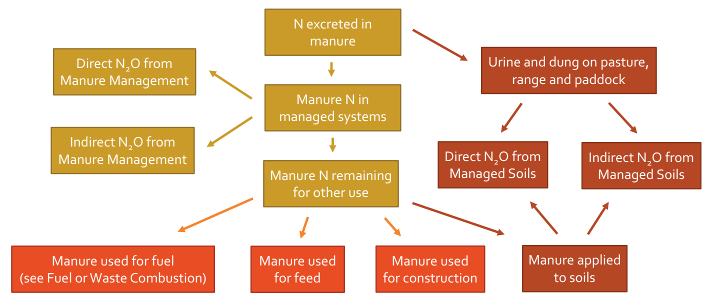
$$VS = \left[\left(1 - \frac{DE}{100}\right) \times GE + (UE \times GE)\right] \times \left(\frac{1-ASH}{18.45}\right)$$ (eq. 10.24)

Parameters:

VS	= Volatile solid excretion	(kg d.m. day^{-1})
DE	= Digestibility of feed	(percent)
GE	= Gross energy intake	(MJ day^{-1})
UE	= Urinary energy	(fraction)
ASH	= Ash content of manure	(fraction)
18.45	= Conversion factor for dietary GE per kg dry matter	(MJ (kg d.m.)$^{-1}$)

(2006 IPCC Guidelines, Vol 4 Ch 10; eq 10.24; pg 10.42)

Managed Manure vs Soil N_2O Emissions



Manure Management Direct N_2O

Equation:

$$N_2O_{MM} = \sum_{s=1}^{S}\left(\sum_{l=1}^{L}\left(AAP_l \times N_{ex_l} \times MS_{l,s}\right) \times EF_s\right) \times \frac{44}{28}$$ (eq. 10.25)

Parameters:

N_2O_{MM}	= N_2O emissions from manure management	(kg N_2O year^{-1})
AAP_l	= Average annual population in livestock category l	(head)
N_{ex_l}	= Nitrogen excretion rate per head in livestock category l	(kg N head^{-1} year^{-1})
$MS_{l,s}$	= Fraction of N excretion by head in livestock category l in manure management system s	(fraction)
EF_s	= N_2O emission factor for manure management system s	(kg N_2O-N (kg N)$^{-1}$)
44/28	= Conversion factor from N_2O-N emissions to N_2O emissions	

(2006 IPCC Guidelines, Vol 4 Ch 10; eq 10.25; pg 10.54)

N Excretion Rate

Equation:

Tier 1 $N_{ex_l} = N_{rate_l} \times \frac{TAM_l}{1{,}000} \times 365$ (eq. 10.30)

Tier 2 $N_{ex_l} = N_{in_l} \times (1 - N_{ret_l})$ (eq. 10.31)

Parameters:

N_{ex_l}	Annual N excretion for livestock category l	(kg N head^{-1} year^{-1})
N_{rate_l}	Default N excretion rate	(kg N (1000 kg animal)$^{-1}$ year^{-1})
TAM_l	Typical animal mass for livestock category l	(kg head^{-1})
N_{in_l}	Annual N intake per head of livestock category l	(kg N head^{-1} year^{-1})
N_{ret_l}	Fraction of annual N intake retained per head of livestock category l	(kg N head^{-1} year^{-1})

(2006 IPCC Guidelines, Vol 4; eq 10.30-31; pg 10.57-58)

Indirect N_2O from Volatilization / Deposition

Equation:

$$N_2O_{MM_{vd}} = \sum_{s=1}^{S}\left(\sum_{l=1}^{L}(AAP_l \times N_{ex_l} \times MS_{l,s}) \times \frac{f_{vol_s}}{100}\right) \times EF_4 \times \frac{44}{28} \quad \text{(eq. 10.26-27)}$$

Parameters:

$N2OMM_{vd}$	= Indirect N_2O emissions due to volatilization of N from manure management	(kg N_2O year^{-1})
AAP_l	= Average annual population in livestock category l	(head)
Nex_l	= Nitrogen excretion rate per head in livestock category l	(kg N head^{-1} year^{-1})
$MS_{l,s}$	= Fraction of N excretion by head in livestock category l in manure management system s	(fraction)
$fvol_s$	= Fraction of manure N that volatilize as NH_3 and NO_x in manure management system s	(fraction)
EF_4	= Emission factor for N_2O emissions from deposition of volatilized N	(kg N_2O-N (kg N)$^{-1}$)
44/28	= Conversion factor from N_2O-N emissions to N_2O emissions	

(2006 IPCC Guidelines, Vol 4 Ch 10; Eq 10.26-27; pg 10.54-56)

Indirect N_2O from Leaching / Runoff

Equation:

$$N_2O_{MM_{lr}} = \sum_{s=1}^{S}\left(\sum_{l=1}^{L}(AAP_l \times N_{ex_l} \times MS_{l,s}) \times \frac{f_{lr_s}}{100}\right) \times EF_5 \times \frac{44}{28} \quad \text{(eq. 10.28-29)}$$

Parameters:

$N2OMM_{lr}$	= Indirect N_2O emissions due to volatilization of N from manure management	(kg N_2O year^{-1})
AAP_l	= Average annual population in livestock category l	(head)
Nex_l	= Nitrogen excretion rate per head in livestock category l	(kg N head^{-1} year^{-1})
$MS_{l,s}$	= Fraction of N excretion by head in livestock category l in manure management system s	(fraction)
flr_s	= Fraction of manure N lost to leaching and runoff in manure management system s	(fraction)
EF_5	= Emission factor for N_2O emissions from N lost to leaching and runoff	(kg N_2O-N (kg N)$^{-1}$)
44/28	= Conversion factor from N_2O-N emissions to N_2O emissions	

(2006 IPCC Guidelines, Vol 4 Ch 10; Eq 10.28-29; pg 10.56-57)

Land Classification Principles

- **Need an adequate classification of land**
  - **Represent land uses as provided by IPCC**
    - **Comparability between countries in reporting**
  - **Further disaggregation by strata as needed to assign emission factors**
- **Need a complete representation of land**
  - **Managed and unmanaged land**
- **Need a consistent application land representation data**
  - **Definitions and classifications are applied consistently**
    - **e.g., managed land base**
  - **Harmonize data as needed**

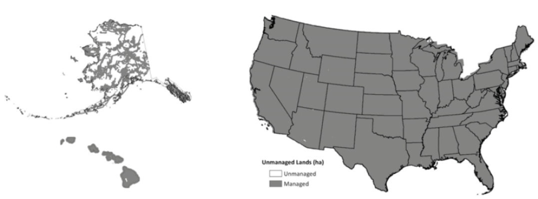
Land Classification Principles

- Ensure all relevant anthropogenic activities are included in land representation
  - All that influence greenhouse gas emissions
- Need to be transparent
  - Classifications
  - Application to methods
  - Assumptions
- Ensure the total land area of country is represented across time series

Managed Land

- Proxy" for anthropogenic activity
  - What are the potential problems with a proxy approach?
- General Definition: Managed land is influenced by direct human intervention
  - What are examples of indirect human intervention?
- All land in domain should be assigned to managed or unmanaged
- Managed land base will typically remain constant over the time series of the GHG inventory

Managed vs Unmanaged Land



Managed Land: Land where human interventions and practices have been applied to perform production, ecological or social functions.

(2006 IPCC Guidelines; Vol 4 Ch 3, pg 3.6)

Land Use Types

- Forest Land
- Grassland
- Cropland
- Wetland
- Settlements
- Other Lands

Land Use Conversion

Defined based on final land use

- FF = Forest Land remaining Forest Land
- GG = Grassland remaining Grassland
- CC = Cropland remaining Cropland
- WW = Wetlands remaining Wetlands
- SS = Settlements remaining Settlements
- OO = Other Land remaining Other Land
- LF = Land converted to Forest Land
- LG = Land converted to Grassland
- LC = Land converted to Cropland
- LW = Land converted to Wetlands
- LS = Land converted to Settlements
- LO = Land converted to Other Land

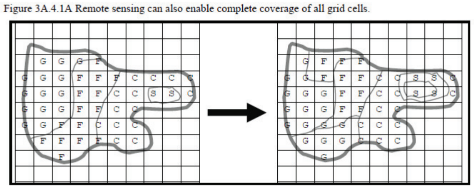
Approaches

1) Total land area, no conversion between land uses
2) Total land area, changes between land uses but not spatially-explicit
3) Spatially-explicit land use land use conversion data

Spatially Explicit Land Representation

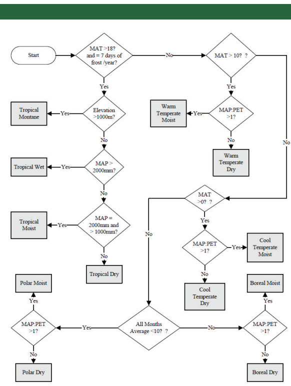
Time 1 Time 2

Figure 3A.4.1A Remote sensing can also enable complete coverage of all grid cells.

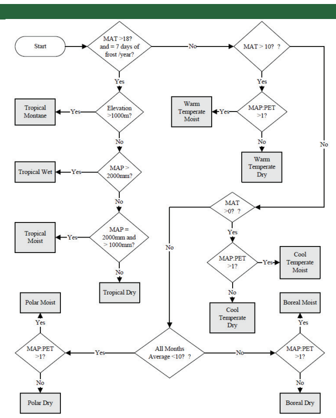


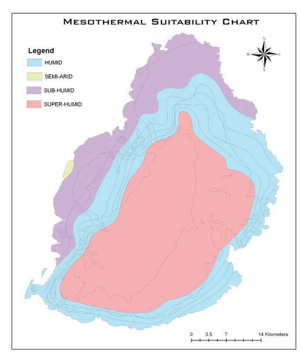
Climate Stratification

- Tropical, montane
- Tropical, wet
- Tropical, moist
- Tropical, dry



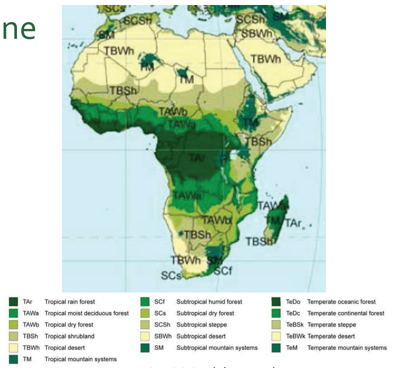
(2006 IPCC Guidelines, Vol 4, Figure 3A.5.2, pg 3.39)





FAO Ecological Zone Stratification

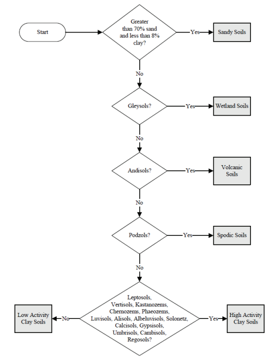
- Tropical rainforest
- Tropical moist deciduous forest
- Tropical dry forest
- Tropical shrubland
- Tropical desert
- Tropical mountain system
- Subtropical humid forest
- Subtropical dry forest
- Subtropical steppe
- Subtropical desert
- Subtropical mountain systems



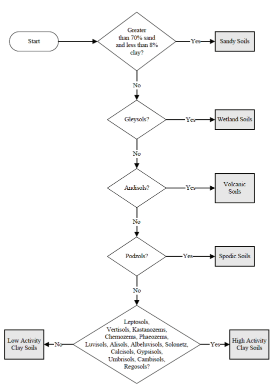
(2006 IPCC Guidelines, Vol 4, Figure 4.1, pg 4.9)

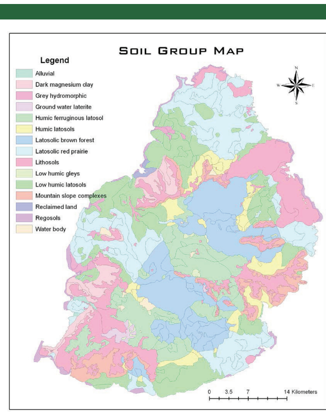
Soil Stratification

- Sandy
- Wetland
- Volcanic
- Spodic
- High activity clay
- Low activity clay
- Organic



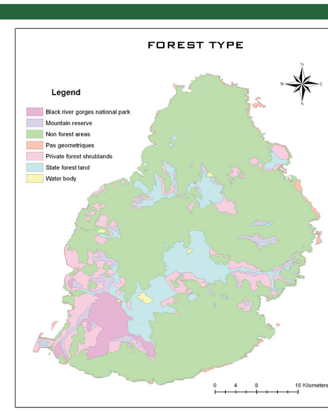
(2006 IPCC Guidelines, Vol 4, Figure 3A.5.4, pg 3.41)





Forest Types

- Common forests
  - Evergreen
  - Deciduous
  - Native
  - Plantations
- Key for assigning stocks, growth increments and other factors needed for estimating the C stock changes



Annual Crop Types

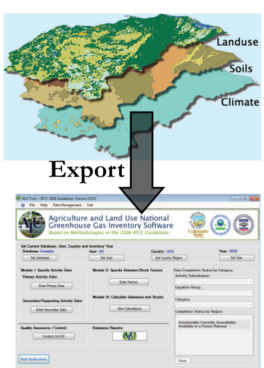
- Common annual crops
  - Cereal crops (maize, wheat, oats)
  - Legumes (beans, peas)
  - Roots and tubers
  - Vegetables
- Biomass C gain = Biomass C loss
- Residues can contribute to:
  - Non-CO_2 emissions from burning
  - N input to soils leading to N_2O emissions
- Major impacts on soil C from
  - Rotations management
  - C inputs from residues
  - Tillage of soil

Perennial Crops

- Common perennial crops
  - Tea
  - Coffee
  - Bananas
  - Oil Palm
  - Cacao
- Biomass C can be estimated using gain-loss or stock difference approaches
- Often limited impact on soil C

GIS Import File

(Geographic Information System)



ALU allows import of data from a GIS

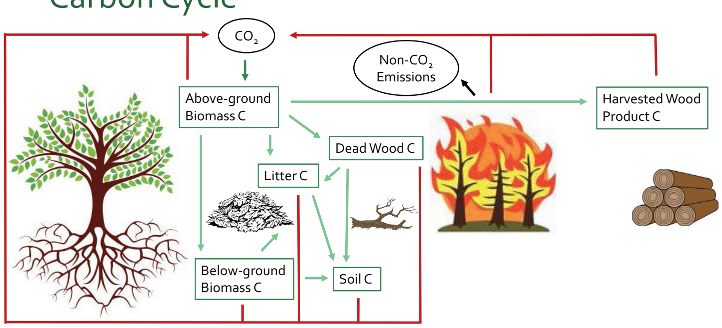
Management Stratification

- Tillage practices (intensive tillage, reduced tillage, no till)
- Cropping systems (crop type, rotation, intensification)
- Grassland management practices (degraded, natural, improved)
- Forest age classes
- Plantation/perennial crop age classes

Matching Land Area with Factors

1) Apply emission factors to the most disaggregated stratification level
2) Use expert judgement when assigning emission factors and for quality assurance
3) Tier 1 default factors were statistically derived from IPCC defined climate, ecological and soil stratification so use such stratification when applying default factors
4) Any new stratification should be clearly mapped to older strata to assist in comparable methodologies

Carbon Cycle



Methods for Forest Land

Sink / Source Category	Sink / Source Subcategory	Tier 1 Method	Tier 2 Method
Forest Land remaining Forest Land	Aboveground / Belowground Biomass	Gain-Loss; IPCC defaults	Gain-Loss, Stock Difference; Country-specific factors
	Litter / Dead Wood	Assume net change is 0	Country-specific methods
	Soil Carbon	Assume net change is 0	Country-specific soil C stock change factors
	Non CO_2 Emissions from Burning	Calculate assuming all C is lost; IPCC defaults	Calculate using country-specific factors
Land converted to Forest Land	Aboveground / Belowground Biomass	Gain-Loss; IPCC defaults	Gain-Conversion-Loss; Country-specific factors
	Litter / Dead Wood	Linear C increase over 20 years; IPCC defaults	Linear C increase over 20 years; IPCC defaults
	Soil Carbon	Soil C stock change factors; IPCC defaults	Country-specific soil C stock change factors
	Non CO_2 Emissions from Burning	Calculate assuming all C is lost; IPCC defaults	Calculate using country-specific factors

Methods for Croplands

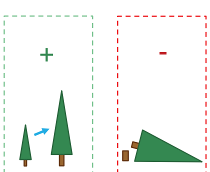
Sink / Source Category	Sink / Source Subcategory	Tier 1 Method	Tier 2 Method
Cropland remaining Cropland	Aboveground / Belowground Biomass	Gain-Loss on perennial / woody croplands; IPCC defaults	Gain-Loss, Stock Difference on perennial / woody croplands; Country-specific factors
	Litter / Dead Wood	Assume net change is 0	Gain-Loss, Stock Difference; Country-specific factors
	Soil Carbon	Soil C stock change factors; IPCC defaults	Soil C stock change factors; Country-specific factors
	Non CO_2 Emissions from Burning	Calculate assuming all C is lost; IPCC defaults	Calculate using country-specific factors
Land converted to Cropland	Aboveground / Belowground Biomass	Gain-Conversion-Loss; IPCC defaults	Gain-Conversion-Loss; Country-specific factors
	Litter / Dead Wood	All C is lost and no accumulation; Best estimates available	Dead Organic Matter Gain-Loss, Stock Difference; Country-specific factors
	Soil Carbon	Soil C stock change factors; IPCC defaults	Soil C stock change factors; Country-specific factors
	Non CO_2 Emissions from Burning	Calculate assuming all C is lost; IPCC defaults	Calculate using country-specific factors

Methods for Grasslands

Sink / Source Category	Sink / Source Subcategory	Tier 1 Method	Tier 2 Method
Grassland remaining Grassland	Aboveground / Belowground Biomass	Assume net change is 0	Gain-Loss, Stock Difference; Country-specific factors
	Litter / Dead Wood	Assume net change is 0	Gain-Loss, Stock Difference; Country-specific factors
	Soil Carbon	Soil C stock change factors; IPCC defaults	Soil C stock change factors; Country-specific factors
	Non CO_2 Emissions from Burning	Calculate assuming all C is lost; IPCC defaults	Calculate using country-specific factors
Land converted to Grassland	Aboveground / Belowground Biomass	Gain-Conversion-Loss; IPCC defaults	Gain-Conversion-Loss; Country-specific factors
	Litter / Dead Wood	All C is lost and no accumulation; Best estimates available	Dead Organic Matter Gain-Loss, Stock Difference; Country-specific factors
	Soil Carbon	Soil C stock change factors; IPCC defaults	Soil C stock change factors; Country-specific factors
	Non CO_2 Emissions from Burning	Calculate assuming all C is lost; IPCC defaults	Calculate using country-specific factors

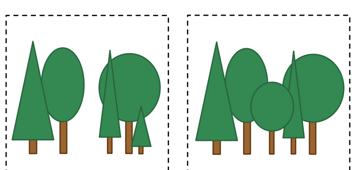
Biomass C Inventory Methods

Gain Loss



2015

Stock Difference



2020 - 2015

Biomass C Gain Loss Method

Equation:

$$\Delta C_B = \Delta C_G - \Delta C_L \qquad \text{(eq. 2.7)}$$

Parameters:

ΔC_B	Annual change in biomass C stocks	(tonnes C year^{-1})
ΔC_G	Annual increase in biomass C stocks due to growth	(tonnes C year^{-1})
ΔC_L	Annual decrease in biomass C stocks due to losses	(tonnes C year^{-1})

(2006 IPCC Guidelines, Vol 4 Ch 2, eq 2.7, pg 2.12)

Biomass Gains

Equation:

$$\Delta C_G = \sum_{j=1}^{J} \sum_{i=1}^{I} A_{i,j} \times G_{T_{i,j}} \times CF$$ (eq. 2.9)

Parameters:

ΔC_G	Annual increase in biomass C stocks due to growth	(tonnes C year^{-1})
$A_{i,j}$	Area of land remaining in ecological zone i, climate j	(ha)
$G_{T_{i,j}}$	Mean annual biomass growth in ecological zone i, climate j	(tonnes d.m. ha^{-1} year^{-1})
CF	Carbon fraction of dry matter	(tonnes C (tonnes d.m.)$^{-1}$)

(2006 IPCC Guidelines, Vol 4 Ch 2, eq 2.9, pg 2.15)

Annual Growth

Equation:

Tier 1: $$G_{T_{i,j}} = \sum_{v=1}^{V} G_{W_{i,j,v}} \times (1 + R_v)$$ (eq. 2.10a)

Tier 2: $$G_{T_{i,j}} = \sum_{v=1}^{V} I_{j,i,v} \times BECF_{I_v} \times (1 + R_v)$$ (eq. 2.10b)

Parameters:

$G_{T_{i,j}}$	Mean annual biomass growth in ecological zone i, climate j	(tonnes d.m. ha^{-1} year^{-1})
$G_{W_{i,j,v}}$	Mean annual biomass growth in ecological zone i, climate j, vegetation type v	(tonnes d.m. ha^{-1} year^{-1})
R_v	Ratio of belowground to aboveground biomass for vegetation type v	(fraction)
$I_{i,j,v}$	Mean net annual increment for vegetation type v, in ecological zone i, climate j	(m^3 ha^{-1} year^{-1})
$BECF_{I_v}$	Biomass conversion and expansion factor for conversion of net annual increment to biomass growth for vegetation type v	(tonnes d.m. m^{-3})

(2006 IPCC Guidelines, Vol 4 Ch 2, eq 2.10, pg 2.15)

Biomass Losses

Equation:

$$\Delta C_L = L_{WR} + L_F + L_D$$ (eq. 2.11)

Parameters:

ΔC_L	Annual decrease in biomass C stocks due to losses	(tonnes C year^{-1})
L_{WR}	Annual biomass C loss due to wood removals	(tonnes C year^{-1})
L_F	Annual biomass C loss due to fuelwood removals	(tonnes C year^{-1})
L_D	Annual biomass C loss due to disturbances	(tonnes C year^{-1})

(2006 IPCC Guidelines, Vol 4 Ch 2, eq 2.11, pg 2.16)

Wood Removals

Equation:

$$L_{WR} = V \times BCEF_R \times (1 + R) \times CF$$ (eq. 2.12)

Parameters:

L_{WR}	Annual biomass C loss due to wood removals	(tonnes C year^{-1})
V	Annual wood removals	(m^3 year^{-1})
$BECF_R$	Biomass conversion and expansion factor for conversion of merchantable volume to total biomass removals	(tonnes d.m. m^{-3})
R	Ratio of belowground to aboveground biomass	(fraction)
CF	Carbon fraction of dry matter	(tonnes C (tonnes d.m.)$^{-1}$)

(2006 IPCC Guidelines, Vol 4 Ch 2, eq 2.12, pg 2.17)

Fuelwood Removals

Equation:

$$L_F = \{[F_W \times BCEF_R \times (1+R)] + [F_P \times D]\} \times CF \quad \text{(eq. 2.13)}$$

Parameters:

L_F	Annual biomass C loss due to fuelwood removals	(tonnes C year^{-1})
F_W	Annual volume fuelwood removals of whole trees	(m^3 year^{-1})
$BCEF_R$	Biomass conversion and expansion factor for conversion of merchantable volume to total biomass removals	(tonnes d.m. m^{-3})
R	Ratio of belowground to aboveground biomass	(fraction)
F_P	Annual volume fuelwood removals of tree parts	(m^3 year^{-1})
D	Wood density	(tonne d.m. m^{-3})
CF	Carbon fraction of dry matter	(tonnes C (tonnes d.m.)$^{-1}$)

(2006 IPCC Guidelines, Vol 4 Ch 2, eq 2.13, pg 2.17)

Disturbances

Equation:

$$L_D = A_D \times B_W \times (1+R) \times CF \times f_D \quad \text{(eq. 2.14)}$$

Parameters:

L_D	Annual biomass C loss due to disturbances	(tonnes C year^{-1})
A_D	Area affected by disturbances	(ha year^{-1})
B_W	Mean aboveground biomass of land affected by disturbance	(tonnes d.m. ha^{-1})
R	Ratio of belowground to aboveground biomass	(fraction)
CF	Carbon fraction of dry matter	(tonnes C (tonnes d.m.)$^{-1}$)
f_D	Fraction of biomass lost in disturbance	(fraction)

(2006 IPCC Guidelines, Vol 4 Ch 2, eq 2.14, pg 2.18)

Biomass C for Land Use Conversion

Equation:

$$\Delta C_C = \sum_{i=1}^{I} \left[\left(B_{A_i} - B_{B_i} \right) \times A_i \right] \times CF \quad \text{(eq. 2.16)}$$

Parameters:

ΔC_C	Initial change in biomass C stocks on land converted to other land use	(tonnes C year^{-1})
B_{A_i}	Biomass stock on land type i immediately after conversion	(tonnes d.m. ha^{-1})
B_{B_i}	Biomass stock on land type i before the conversion	(tonnes d.m. ha^{-1})
A_i	Area of land type i converted in the inventory year	(ha year^{-1})
CF	Carbon fraction of dry matter	(tonnes C (tonnes d.m.)$^{-1}$)

(2006 IPCC Guidelines, Vol 4 Ch 2, eq 2.16, pg 2.20)

Biomass C Stock Difference Method

Equation:

$$\Delta C_B = \frac{C_{t_2} - C_{t_1}}{t_2 - t_1} \qquad C = A_{i,j} \times V_{i,j} \times BCEF_S \times (1+R) \times CF \quad \text{(eq. 2.8)}$$

Parameters:

ΔC_B	Annual change in biomass C stocks	(tonnes C year^{-1})
$A_{i,j}$	Area of land remaining in ecological zone i, climate j	(ha)
$V_{i,j}$	Volume of merchantable growing stock in ecological zone i, climate j	(m^3 year^{-1})
$BCEF_S$	Biomass conversion and expansion factor for conversion of merchantable growing stock volume to aboveground biomass	(tonnes d.m. m^{-3})
R	Ratio of belowground to aboveground biomass	(fraction)
CF	Carbon fraction of dry matter	(tonnes C (tonnes d.m.)$^{-1}$)

(2006 IPCC Guidelines, Vol 4 Ch 2, eq 2.8, pg 2.12)

Perennial Cropland Biomass

Gain Loss Methods
- Biomass C gains taken from Table 5.1
- Biomass C losses are assumed upon harvest and also take from Table 5.1
- Over the production cycle the losses will equal the gains
- Tier 2 approach can apply country specific accumulation and loss rates

Stock Difference Method
- Tier 2 approach uses country derived stock volumes from field research

Non-CO_2 Emissions from Biomass Burning

Equations:

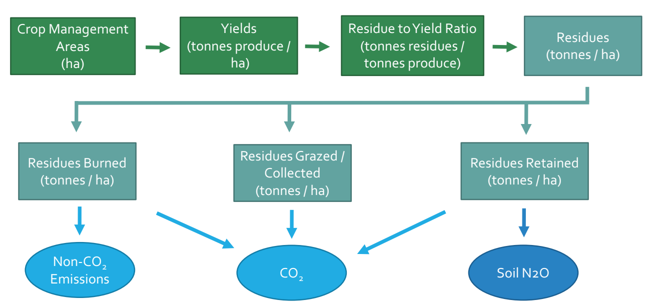
$$F_g = \frac{A_t \times M \times C \times G_g}{1{,}000} \qquad \text{(eq. 2.27)}$$

Parameters:

F_g	Amount of greenhouse gas emissions from fire for gas g	(tonnes gas year^{-1})
A_t	Area burnt in year t	(ha year^{-1})
M	Mass of fuel available for combustion	(tonnes d.m. ha^{-1})
C	Combustion factor	(fraction)
G_g	GHG emission factor for gas g	(g gas (kg d.m.)$^{-1}$)

(2006 IPCC Guidelines, Vol 4 Ch 2; Eq 2.27; pg 2.42)

Crop Residue Management



Soil Carbon Stock Changes

Dead Organic Matter Land Use Conversion

Equation:

$$\Delta C_{DOM} = A \times \frac{C_{new} - C_{old}}{T} \quad \text{(eq. 2.23)}$$

Parameters:

ΔC_{DOM} Annual change in C stocks in the dead organic matter pools (tonnes C year^{-1})

A Area of land undergoing conversion (ha)

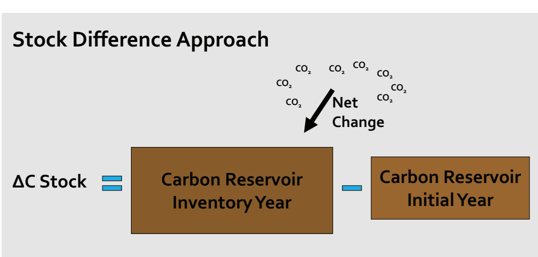
C_{new} Dead organic matter C stock under the new land use category (tonnes C ha^{-1})

C_{old} Dead organic matter C stock from the old land use category (tonnes C ha^{-1})

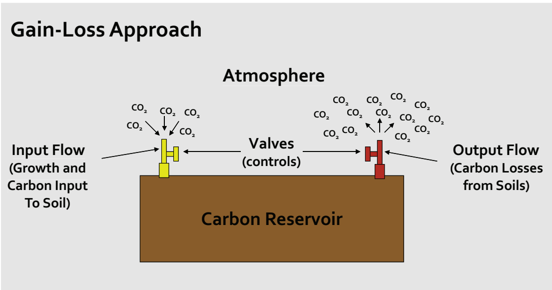
T Time period of transition from the old to new land use category (years)

(2006 IPCC Guidelines, Vol 4 Ch 2, eq 2.23, pg 2.26)

Mineral Soils



Organic Soils



Mineral Soil C Stock Change

Equation:

$$\Delta C_S = \frac{SOC_0 - SOC_T}{D} \qquad \text{(eq. 2.25a)}$$

Parameters:

ΔC_S	Annual change in mineral soil C stocks	(tonnes C year^{-1})
SOC_T	Soil organic C stock in the last year of an inventory period, T	(tonnes C)
SOC_0	Soil organic C stock at the beginning of an inventory period, 0	(tonnes C)
D	Time dependence of stock change factor	(years)

(2006 IPCC Guidelines, Vol 4 Ch 2, eq 2.25, pg 2.30)

Soil C Stock Change Factors

Equation:

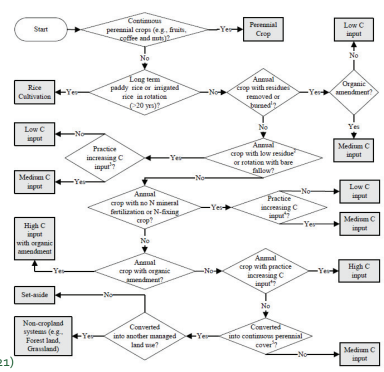
$$SOC = \sum_{c=1}^{C}\sum_{s=1}^{S}\sum_{m=1}^{M}\left(SOC_{Ref_{c,s,m}} \times A_{c,s,m} \times F_{LU} \times F_{MG} \times F_I\right) \qquad \text{(eq. 2.25b)}$$

Parameters:

SOC	Soil organic carbon stock	(tonnes C)
$A_{c,s,m}$	Area of land for climate c, soil type s, management type i	(ha)
$SOC_{Ref_{c,s,m}}$	Reference soil organic C stock for climate c, soil type s	(tonnes C ha^{-1})
F_{LU}	Stock change factor of land-use system	(fraction)
F_{MG}	Stock change factor of management regime	(fraction)
F_I	Stock change factor of organic matter inputs	(fraction)

(2006 IPCC Guidelines, Vol 4 Ch 2, eq 2.25, pg 2.30)

Assigning C Stock Change Factors



(2006 IPCC Guidelines, Vol 4 Ch 5, Fig 5.1, pg 5.21)

THANKS FOR YOUR ATTENTION!

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Thanks to Matt Ramlow of Colorado State University for assistance in preparing slides!

Annex VI: Attendance Certificate

THIRD NATIONAL COMMUNICATION FOR THE REPUBLIC OF MAURITIUS UNDER THE UNITED NATIONS FRAMEWORK CONVENTION ON CLIMATE CHANGE

Training on the Application of the Agriculture and Land Use (ALU) Software Version 5.0

This is to certify that

XXXXXXXXXXXXXX

has successfully completed the above training
held at the University of Mauritius, Réduit
from 24 to 28 July 2017

....

Nema Devi Goorah
Permanent Secretary
Ministry of Social Security, National Solidarity, and Environment and Sustainable Development (Environment and Sustainable Development Division)

....

Dr Stephen M. Ogle
Senior Scientist and Associate Professor
Natural Resource Ecology Laboratory and Department of Ecosystem Science and Sustainability
Colorado State University