Mémoire

présenté pour l'obtention du Master

Mention : Eau
Spécialité : Eau et Agriculture

Impacts de la riziculture d'Asie du Sud-Est sur le changement climatique: comparaison des méthodes d'évaluation

par Wanndet DIM

Année de soutenance : 2015

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Mémoire de stage

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ខ្លឹមសារសង្ខេប

កត្តាចំបងដែលបំពុល ទៅលើបរិយាកាស នូវក្នុងការដាំដុះដំណាំស្រូវ គឺឧស្ម័នមេតាន (CH_4) ដោយវាជាប្រភពឧស្ម័នសំខាន់ ក្នុងការបំផ្លិចផ្លាញបរិស្ថាន ដោយវាកើតចេញពីទង្វើ និងរាល់សកម្មភាពផ្សេងៗ ក្នុងការបំភាយឧស្ម័នផលផ្ទះកញ្ចក់ (GHG)។ ការសិក្សាមួយចំនួន បានធ្វើការស៊ើបអង្កេត លើលក្ខណៈស្រដៀងគ្នា និងខុសគ្នា នៃការផ្លាស់ប្តូរបរិស្ថាន ទៅតាមតំបន់ដែលបំផ្លិចផ្លាញបរិយាកាស ដោយបូកបញ្ចូលនូវ រាល់សកម្មភាពរបស់មនុស្ស ក្នុងការដាំដុះដំណាំស្រូវ ជាទូទៅដូចជា ការគ្រប់គ្រងប្រព័ន្ធធារាសាស្ត្រ និងក៏ដូចជាការគ្រប់គ្រងទឹកផងដែរ។ នៅក្នុងរបាយការណ៍នេះ វិធីសាស្ត្រនិងកម្មវិធីសំខាន់ពីរ យកមកសិក្សា (EX-Ante C-balance Tool និងការវាយតម្លៃវដ្តជីវិត, LCA) ដោយត្រូវបានគេ យកមកប្រើប្រាស់ ដើម្បីប្រៀបធៀប និងវិភាគពីតម្លៃផលប៉ះពាល់ នៃដំណាំស្រូវនៅក្នុងតំបន់ខ្ពង់រាប និង ដំណាំស្រូវទូទៅ នៅប្រទេសអាស៊ីអាគ្នេយ៍ ទៅតាមបណ្តោយអាកាសធាតុសណ្ឋានដី។ ប្រព័ន្ធអេកូឡូស៊ីសម្រាប់ដំណាំស្រូវដែលលេចទឹក បាទចែកភទស្រូវជាបួនធំៗទៅតាមតំបន់ ដោយផ្អែកទៅលើ របបទឹក, ប្រព័ន្ធបណ្តោះទឹក, សីតុណ្ហភាព, ដី និងទីតាំងភូមិសាស្ត្រ។ លទ្ធផលបានបង្ហាញថា ប្រព័ន្ធអេកូឡូស៊ីស្រូវទាំងបួបនេះ (ស្រូវតំបន់ខ្ពង់រាប, ស្រូវពឹងផ្អែកលើទឹកភ្លៀង, ស្រូវទឹកលេច, ស្រូវដោយប្រព័ន្ធស្រោចស្រព) គឺវាមានភាពគ្រប់គ្រាន់ ដើម្បីធ្វើការសិក្សាទៅលើបញ្ហាបរិស្ថាន។ វាក៏បានគូសបញ្ជាក់ទៀតថា ការដំណាំស្រូវក្នុង តំបន់ខ្ពង់រាប វាបានស្រូបនូវ បរិមាណឧស្ម័នកាបូនិច ជាពិសេស ក្នុងការប្រើប្រាស់ ជីលាមកសត្វ ដោយមានកម្រិត នៃការស្រូប ប្រហែល 2.5 តោន ដែលមានតម្លៃស្មើទៅនឹង កាបូនឌីអុកស៊ីតក្នុងមួយហិកតា និង 6.22 តោន ដែលមានតម្លៃស្មើទៅនឹងកាបូន ឌីអុកស៊ីត ក្នុងមួយតោននៃទិន្នផល។ នៅក្នុងដំណាំស្រូវក្នុងតំបន់ដែលមានប្រព័ន្ធស្រោចស្រព, ការគ្រប់គ្រងទឹក ក៏ដូចជាប្រព័ន្ធធារាសាស្ត្រ និងប្រព័ន្ធបង្ហូរទឹក គឺជាបញ្ហាដ៏សំខាន់ នៅក្នុងការគ្រប់គ្រងភាពប៉ះពាល់ នៃឧស្ម័នផ្ទះកញ្ចក់ ដែលបានសាយភាយរីបញ្ចេញ។ កម្រិតនៃការបង្ហូរទឹកចេញពីស្រែ វាក៏មានផលប៉ះពាល់លើ ការបញ្ចេញឧស្ម័នផ្ទះកញ្ចក់ ដោយមានការផ្លាស់ប្តូរពី 4 ទៅ 5 ដង ទៅតាមកំរិតនៃ ការបណ្តោះទឹក។ ជាងនេះដែរ ការគ្រប់គ្រងប្រព័ន្ធដកទឹកដែលមិនបានត្រឹមត្រូវ វាបានបង្ហាញថា ការបំភាយឧស្ម័នគឺខ្ពស់បំផុត (7.78 តោន ដែលមានតម្លៃស្មើទៅនឹងកាបូនឌីអុកស៊ីត ក្នុងមួយហិកតា) ខណៈពេលដែលប្រព័ន្ធនេះ មានការបង្ហូរទឹក ក្នុងអំឡុងពេលដាំដុះ (2,29 តោន ដែលមានតម្លៃស្មើទៅនឹង កាបូនឌីអុកស៊ីតក្នុងមួយហិកតាសំរាប់លក្ខខណ្ឌ័គ្មានការជន់លេច) វាក៏បានបង្ហាញថា ការបំភាយនេះ មានកម្រិតដូចគ្នានៃប្រព័ន្ធស្រូវដែលពឹងផ្អែកលើទឹកភ្លៀង។ ជាចុងក្រោយ ប្រព័ន្ធស្រូវលេចទឹក រួមជាមួយនឹងប្រព័ន្ធដែលមាន ការបង្ហូរទឹក ក្នុងអំឡុងពេលដាំដុះ គឺបានបង្ហាញថាវាអន្តរការី (4,35 តោន ដែលមានតម្លៃស្មើទៅនឹងកាបូនឌីអុកស៊ីត ក្នុងមួយហិកតា) ។ វិធីសាស្ត្រក្នុងក្របខ័ណ្ឌ (មេគុណជាលំនាំដើម សម្រាប់ថ្នាក់ទី 1 និង តាមតំបន់សិក្សាជាមេគុណជាតិ សម្រាប់ថ្នាក់ទី 2) មានឥទ្ធិពលខ្ពស់ ទៅលើឧស្ម័នផ្ទះកញ្ចក់ សម្រាប់ដំណាំស្រូវអង្ករទាំងអស់, លើកលែងតែ ដំណាំស្រូវដែលពឹងផ្អែកលើទឹកភ្លៀង។ ដំណាំស្រូវក្នុងប្រព័ន្ធធារាសាស្ត្រ, មានលទ្ធផលកើនឡើងទ្វេដង នៃការបំភាយសរុប ដែលគិតចេញពីវិធីសាស្ត្រលំដាប់ថ្នាក់ទី 2 ។ នៅពេលការគណនា នូវការបញ្ចេញឧស្ម័ន ត្រូវបានធ្វើការសិក្សា លើមាត្រដ្ឋានមួយដោយធៀបនឹងសក្តានុពលទិន្នផលស្រូវជាមធ្យម (4-5 តោន/ហិកតាសំរាប់ស្រូវទឹកលេច, 5-7 តោន/ហិកតាសំរាប់ពឹងផ្អែកលើទឹកភ្លៀង, 12-13 តោន/ហិកតាសំរាប់ស្រូវ ដែលមានប្រព័ន្ធស្រោចស្រព), ប្រព័ន្ធដែលមានការបង្ហូរទឹក ក្នុងអំឡុងពេលដាំដុះ មានការតំលៃដូចគ្នាទៅនឹង ប្រព័ន្ធស្រូវ ដែលពឹងផ្អែក លើទឹកភ្លៀង ដែរ។ ប្រព័ន្ធស្រូវដែលបន្តជន់លេច ក្នុងអំឡុងពេលដាំដុះ ជាមួយនឹងតំបន់ដែលមានទឹកគ្រប់រដូវ គឺវានៅតែផ្តល់ផលអវិជ្ជមាន ក្នុងលក្ខខណ្ឌ នៃផលប៉ះពាល់អាកាសធាតុ។ ស្រូវទឹកលេច គឺមានភាពអន្តរការីយ៉ាងខ្លាំងដោយផ្អែកលើបរិបទប្រទេសមួយៗ។ បើទោះបីជា វិធីសាស្រ្តទាំងពីរបានបង្កើតឡើង ដើម្បីដោះស្រាយបញ្ហាផ្សេងៗគ្នាក៏ EX-ACT និង LCA បានផ្តល់ផលប៉ះពាល់នៃការបំភាយឧស្ម័នផ្ទះកញ្ចក់ស្រដៀងគ្នា។

ពាក្យគន្លឹះ

ឧស្ម័នផលផ្ទះកញ្ចក់, EX-Ante C-balance Tool, ការវាយតម្លៃវដ្តជីវិត, ស្រូវតំបន់ខ្ពង់រាប, ដំណាំស្រូវ, ប្រព័ន្ធធារាសាស្ត្រ

RÉSUMÉ

Un des principaux responsables de la pollution de l'environnement dans la culture du riz est le méthane (CH_4) qui représente une importante source anthropique de gaz à effet de serre (GES) atmosphérique. Peu d'études ont étudié les similitudes ou les différences dans changements environnementaux régionaux induits par les modes de gestions tels que l'irrigation et plus généralement la gestion de l'eau. Dans ce rapport, deux approches principales et leurs outils correspondants (EX-Ante C-balance Tool, EX-ACT et l'Analyse du Cycle de Vie, ACV) sont utilisées pour comparer et évaluer l'impact des systèmes riz pluvial et rizicoles d'Asie du Sud-Est. Pour les systèmes inondés, la typologie consiste en quatre grands systèmes qui sont basés sur le régime hydrique, le drainage, la température, le type de sol et la topographie. Les résultats montrent que la typologie retenue (riz pluvial, riz inondé, riz inondé à submersion profonde et le riz irrigué) est adéquate pour représenter les systèmes de gestion d'un point de vue environnemental. Il est souligné que la culture de riz pluvial présente des bilans de carbone, en particulier lors de l'application de fumier, avec un taux de séquestration de 2,5 tonnes équivalent CO_2 par hectare cultivé et 0,62 tonnes équivalent CO_2 par tonne de riz produit. Dans les systèmes irrigués, la gestion de l'eau (l'irrigation et le drainage) est primordiale dans le contrôle de la quantité émise de GES. En intensifiant le niveau de drainage, l'impact sur les émissions de GES peut être modifié par un facteur allant jusqu'à 4 à 5. Les systèmes sans contrôle du drainage présentent les émissions les plus élevées (7,78 tonnes équivalent CO_2 par hectare cultivé), tandis que par les systèmes inondés par intermittence (2,29 tonnes équivalent CO_2 par hectare cultivé, sans présaison inondée) peuvent présenter des émissions du même niveau que des systèmes pluviaux. Enfin, avec une présaison inondée, les systèmes montrent une situation intermédiaire (4,35 tonnes équivalent CO_2 par hectare cultivé). L'approche par niveau (coefficients par défaut, dit de niveau-1 ou de Tier-1, ou coefficients régionaux voire nationaux pour le niveau-2, ou Tier-2) a un fort effet sur les bilans de GES pour tous les systèmes de riz, à l'exception des systèmes pluviaux. Dans les systèmes irrigués, l'approche Tier-2 se traduit par un doublement des émissions totales. Lorsque les émissions sont rapportées au rendement moyen potentiel de chaque catégorie (4-5 t/ha pour le riz en eau profonde, 5-7 t/ha pour le riz pluvial de plaine, 12-13 t/ha pour le riz irrigué), les systèmes inondés avec un drainage intermittent sont aussi émissifs que les systèmes pluviaux. Les systèmes inondés en permanence avec une présaison inondée demeurent les pires systèmes en termes d'impact climatique. Le riz en eau profonde présente une situation intermédiaire mais qui varie fortement en fonction des pays. Même si les deux approches ont été développées pour répondre à différentes problématiques, EX-ACT et les approches de l'ACV fournissent des niveaux similaires d'émissions de GES.

Mots clés

gaz à effet de serre, EX-Ante C-balance Tool, Analyse du Cycle de Vie, riz pluvial, rizicoles, irrigation

ABSTRACT

One of the major environmental pollutant in rice cultivation is methane (CH_4) which represents an important anthropogenic source of atmospheric greenhouse gas (GHG). Few studies have investigated the similar and different characteristics of regional environmental change induced by taking into account the management of those systems such as irrigation and more generally the water management. In this report, two main approaches and their corresponding tools (EX-Ante C-balance Tool, EX-ACT and Life Cycle Assessment, LCA) were used to compare and to evaluate the impact of upland and paddy rice typologies in South-East Asia along a catena. For the flooded rice systems, the typology considers four major systems which are based on water regime, drainage, temperature, soil type and topography. Results show that the typology used (upland, rainfed low land, deep-water and irrigated rice) is adequate to represent the management systems with an environmental point of view. It is highlighted that the upland rice cultivation presents low carbon budgets, especially within the manure application, with a sequestration rate of 2.5 tCO_2-eq per ha cultivated and 0.62 tCO_2-eq per ton of rice produced. In irrigated systems, water management such as irrigation and drainage is key issue in controlling the amount GHG emitted. Deeping of the level of drainage, the impact on the GHG emissions can be changed by a factor up to 4 to 5. The non-controlled drainage systems present the highest emissions (7.78 tCO_2-eq per ha cultivated), while intermittently flooded system by drainage (2.29 tCO_2-eq per ha cultivated, without flooded preseason) can present emissions of the same level of the rainfed systems. Finally with a flooded preseason, systems present an intermediary situation (4.35 tCO_2-eq per ha cultivated). The tier approach (default coefficient for Tier-1, and regional of national coefficient for Tier-2) has a high effect on GHG budgets for all rice systems, except rainfed systems. In Irrigated systems, the Tier-2 approach results in a doubling of total emissions. When emissions are scaled by potential average yield of each category (4-5 t/ha for deep-water rice, 5-7 t/ha for rainfed lowland rice, 12-13 t/ha for irrigated rice), intermittently flooded system by drainage perform as well as Rainfed systems. Continuously flooded systems with flooded preseason remain the worst systems in terms of climate impact. Deep-water rice shows an intermediary situation strongly depending of the country context. Even if the two approaches were developed to address different issues, EX-ACT and LCA approaches gave similar levels of GHG emissions.

Key words

greenhouse gas, EX-Ante C-balance Tool, Life Cycle Assessment, upland rice, paddy rice, irrigation

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FOREWORD

The purpose of this report is to present and evaluate the methods and tools of environmental assessment by analyzing the results from the first round of data collection in the "Southeast Asia Rice Ecosystem project", that concerns typical countries in major rice producing regions of Cambodia, Laos PDR, Myanmar, Thailand and Vietnam.

The report contains four main parts: chapter 1 introduce the framework conditions for producing rice in individual countries, presenting as well the key characteristics of the typical cultivation systems which have been established. Chapter 2 presents the material and methodologies for a cross-country comparison of key parameters of greenhouse gas emission to the atmosphere. Chapter 3 focuses on result and discussion while chapter 4 with main conclusions.

The typical farm data show significant differences within rice cultivation area and rice production systems. While Thailand and Vietnam produce more intensively with high yields and high input levels – in particular as far as the use of fertilizers and seeds is concerned - farms in Cambodia and Myanmar grow rice more extensively while Laos seems to be in an intermediate level.

ABBREVIATIONS, UNITS AND ACRONYMS

AB	:	Above-ground biomass
ADB	:	Asian Development Bank
AEZ	:	Agroecological zone
AFD	:	Agence Française de Développement
AFOLU	:	Agriculture, Forestry and Other Land Use
AP	:	Acidification Potential
APT	:	AgroParisTech
AUF	:	Agence de université de la Francophonie
BB	:	Below-ground biomass
C	:	Carbon
CH_4	:	Methane
CO_2	:	Carbon dioxide
CO_2-eq	:	Carbon dioxide equivalent
DPR	:	Deep-water percolation
DR	:	Deep-water rice
DW	:	Deadwood
EF	:	Emission factor
EFc	:	Baseline emission factor
Ei	:	Irrigation efficiency
EP	:	Eutrophication Potential
ET	:	Evapotranspiration
EX-ACT	:	EX-Ante C-balance Tool
FAO	:	Food and Agriculture Organization of the United Nations
FAOSTAT	:	Food and Agriculture Organization Corporate Statistical Database
FU	:	Functional unit
FWAE	:	Freshwater Aquatic Ecotoxicity
GHG	:	Greenhouse gas
Gt	:	Gigatonnes
GWP_{100}	:	Global warming potential
HFCs	:	Hydroflurocarbons
HWP	:	Harvested wood products
I	:	Irrigation water
Id	:	Dry-Season Irrigated Rice
IPCC	:	Intergovernmental Panel for Climate Change
IR	:	Irrigated rice
IRD	:	Institut de recherche pour le développement
IRRI	:	International Rice Research Institute
IRSTEA	:	Institut national de recherche en sciences et technologies pour l'environnement et l'agriculture
Iw	:	Wet-Season Irrigated Rice
LCA	:	Life cycle analyze/assessment
LCI	:	Life cycle inventory

LCIA	:	Life cycle impact assessment
LI	:	Litter
N_2O	:	Nitrous oxide
NO	:	Nitric oxide
ODP	:	Ozone Depletion Potential
P	:	Precipitation
	:	Phosphorus
PFCs	:	Perfluorocarbons
R	:	Runoff
RR	:	Rainfed lowland rice
Rw	:	Wet-Season Rainfed Low Land Rice
SE	:	Southeast
SF6	:	Sulphurhexafluorides
SFo	:	Scaling factor of organic amendments
SFp	:	Scaling factor of water regime before the cultivation period
SFr	:	Scaling factor of rice cultivar
SFs	:	Scaling factor of soil type
SFw	:	Scaling factor of water regime during the cultivation period
SO	:	Soils
SOM	:	Soil organic matter
UM	:	Université Montpellier
UNFCCC	:	United Nations Framework Convention on Climate Change

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CHAPTER I: INTRODUCTION

I. Introduction

I.1. General context

Global anthropogenic greenhouse gas emissions, GHG have grown about 80% between 1970 and 2004, from 21 to 38 gigatonnes and represented 77% in 2004 as presented in Annexe 1, while the rate of growth of CO_2-eq emissions was much higher during the recent 10-year period of 1995-2004 (0.92 $GtCO_2$-eq per year) than during the previous period of 1970-1994 (0.43 $GtCO_2$-eq per year). Agriculture, Forestry, and Other Land Use (AFOLU) sector plays a central role for food security and it is a critical resource where stands on sustainable development where agriculture's domain stays at the top of globalization in the providing food for 7 billion habitants (Edenhofer, O. et al., 2014). While AFOLU is responsible for a quarter of global GHG emission, the agriculture sector has consider as a mitigation potential source and it is a major source of GHG and directly contributing to 14% of total global emissions (Smith, P. et al., 2007).

The Intergovernmental Panel for Climate Change 4th Assessment Report (IPCC, 2007) states that Southeast Asia was expected to be seriously affected by the adverse impacts of climate change (Smith, P. et al. 2007). Since its economy relies on agriculture and natural resources as primary income, climate change has been and will continue to be a critical factor affecting productivity in the region. In the last five years, there has been an increase in the number of floods and periods of drought, and some of the most devastating cyclone. In Indonesia, the Philippines, Thailand and Viet Nam, the annual mean temperatures are projected to rise by 4.8 °C by 2100, and the global mean sea level will increase by 70 cm during the same period (ADB, 2009).

For instance, emissions of carbon dioxide (CO_2) could be reduced through the adoption of improved cropland management practices (Bernoux et al., 2003) while emissions of methane (CH_4) and nitrous oxide (N_2O) could be reduced through improved animal production, improved management of livestock waste, more efficient management of irrigation water on rice paddies, and improved nutrient management (Cerri et al., 2010). Thus, many rural development projects promoting the adoption of sustainable agriculture and land management practices could play an important role in mitigation, either by reducing emissions or by sequestering carbon, at the same level to increased food security, improved livelihoods and reduced rural poverty (Palmer & Silber, 2012).

I.2. State of the art

I.2.1. Framework of rice production in South-East Asia

Rice is one of the most ingredients food production within Asia (ADB, 2009) and it is also staple foods for more than half of the world's population (IRRI, 2006) which influences the livelihoods and economies of several billion people. Paddy rice production is contributing to climate change since it is a major source of CH_4 (Bachelet & Neue, 1993; Roder et al., 1997; Sasaki, 2006).

In 2010, approximately 154 million ha were harvested worldwide, of which 137 million ha (88 percentages of the global rice harvested) were in Asia – of which 48 million ha (31 percentages of the global rice harvested) were harvested in SE Asia alone in Figure 1, (Redfern et al., 2012). As the political, economic, and social significance in the agricultural countries of the Association of South-East Asian Nations (ASEAN), rice remains the most important crop grown in SE Asia (Mutert and Fairhurst, 2002).

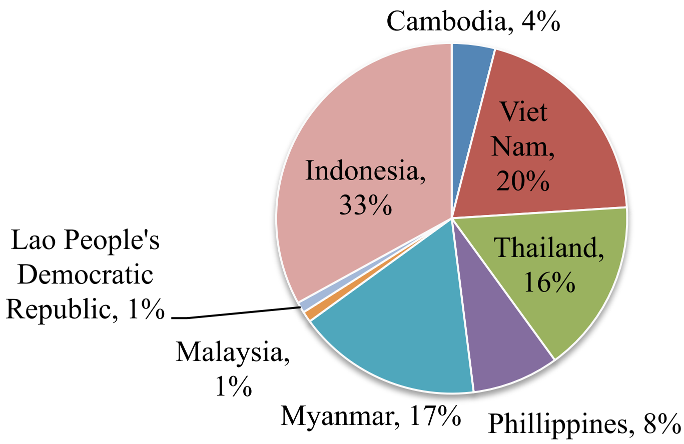


Figure 1: Production of rice paddy in 2010

Source: FAOSTAT, 2012

This study area encompasses five countries in SE Asia, ranging from 68ºE to 142ºE and 10ºS to 35º as on Figure 2. The region contains a variety of climate zones including tropical and subtropical areas in SE Asia. In the areas where rice growth is limited by precipitation or temperature, there is usually one rice crop per year, as in most of the dry and temperate zones. However, in many of the tropical regions, two rice crops per year are common and, in some areas (such as the Mekong Delta in Vietnam), three crops per year are grown. Seasonal patterns of precipitation are driven by the monsoon climate system that dominates over the Indian subcontinent and SE Asia. The monsoons are seasonal winds that bring torrential rains in the summer (May/June to September/October) and the winter is sunny and dry weather.

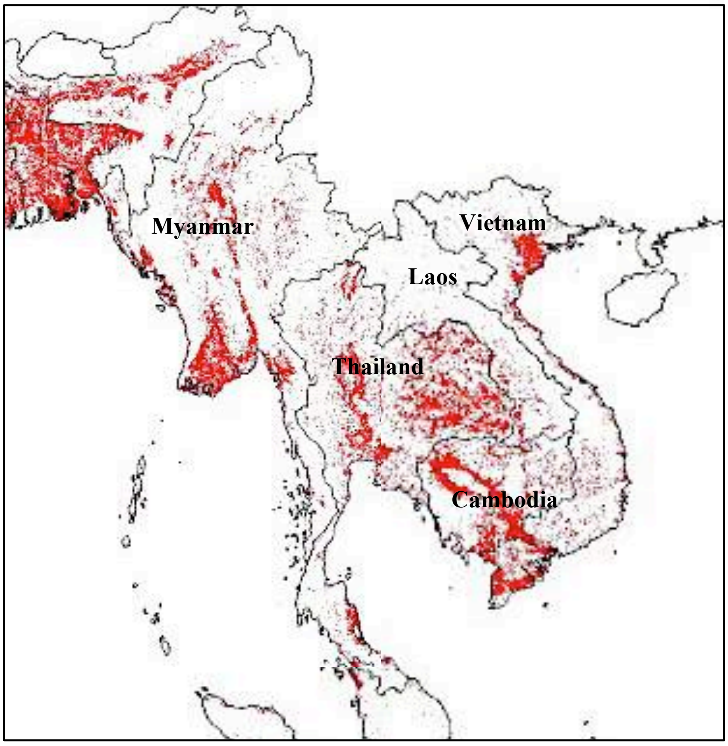


Figure 2: Spatial distribution of paddy rice derived from analysis of MODIS[1] 8-day surface reflectance data in 2002 for South-East Asia, the resultant paddy rice map has a spatial resolution of 500 m

Source: (Xiao et al., 2006)

Base on Table 1, national-level rice in Cambodia is concentrated in the lowlands surrounding lake Tonle Sap and the lower reaches of the Mekong River in the southern part of the country as shown in Figure 2. The majority of rice in this country is rainfed. In Laos, over 35% of the rice crop is upland, the largest percentage of any country in our study. In Myanmar, rice cultivation occurs throughout much of northern part of the country, but majority of the rice production occurs in the delta areas of the Ayeyarwady and Sittoung River. Of the total rice area, rainfed rice accounts for 52%, irrigated rice is 18%, deep-water rice is 24% and upland rice is 6%. While rice is distributed over much of Thailand in Figure 2, nearly half of the rice land is located in the northeast interior region, where the majority of the rice fields are rainfed. In Vietnam, much of the rice cultivation is concentrated in two river deltas, the Mekong (over half of the country's rice area) and the Red River. The rice-sown area in 2000 was about 7.7 million ha and the cropping intensity (ratio of sown area to land area for a given crop) was about 183% (Maclean et al., 2002), the highest in the world. The

[1] Moderate Resolution Imaging Spectroradiometer, MODIS: sensor onboard the NASA EOS Terra satellite

high cropping intensity is largely due to the triple rice crops that are common in much of the Mekong Delta area. Over 92% of the total rice area in Vietnam is either irrigated or rainfed.

Table 1: National-level rice area estimation of rice cultivation categories in five countries of South-East Asia

Country	Area of rice category (x 000 ha) in Huke (1997) and IRRI Rice facts 2002 in Mutert and Fairhurst (2002)											
	Upland		Deep-water		Irrigated paddy		Rainfed paddy		Total		Total (Irrigated + Rainfed)	
	1	2	1	2	1	2	1	2	1	2	1	2
Cambodia	25	33	152	614	305	154	1,418	1,124	1,900	1,925	1,723	1,278
Laos	219	201	-	-	44	40	348	319	611	560	392	359
Myanmar	214	84	362	602	3,198	1,124	2,511	4,166	6,285	5,976	5,709	5,290
Thailand	203	36	342	117	939	2,075	8,160	6,792	9,644	9,020	9,099	8,867
Vietnam	322	345	177	778	3,260	3,687	2,614	1,955	6,373	6,765	5,874	5,642
Total	983	699	1,033	2,111	7,746	7,080	15,051	14,356	24,813	24,246	22,797	21,436

Reference: 1. Huke and Huke (1997)
2. Mutert and Fairhurst (2002)

I.2.2. Typologies of rice field ecosystem in South-East Asia

In the early of eighties, the terminology in the different types of rice cultivation perform throughout the world and are particularly in the South-East Asia (Trébuil & Hossain, 2004). The comprehensive classification presented in Table 2 including four major types of rice farms with subdivided into 18 sub-ecosystems.

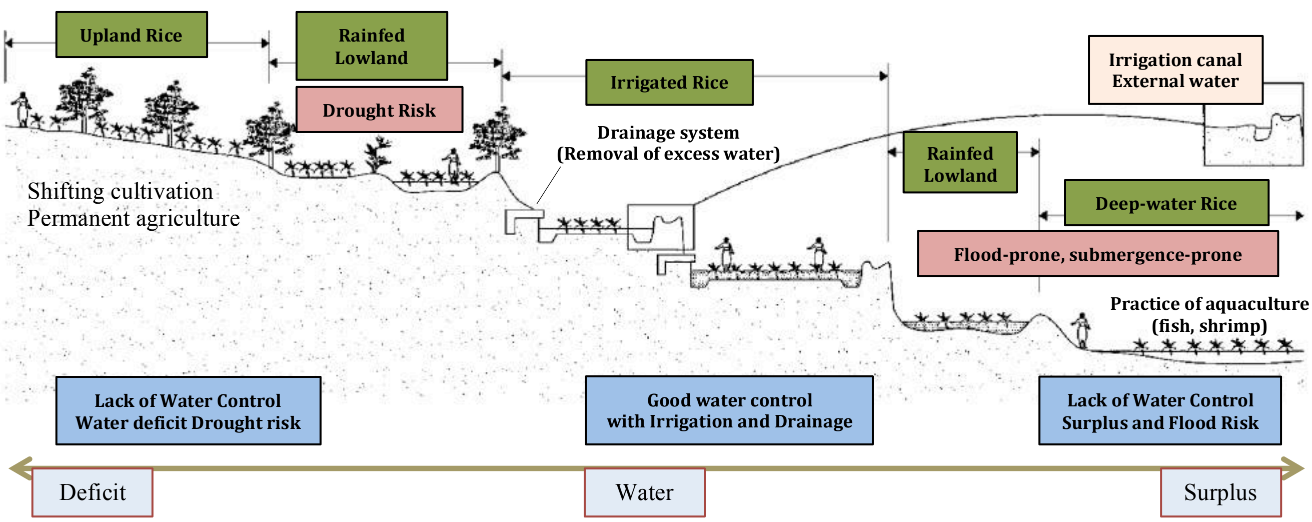


Figure 3: Schematic representation of the major rice ecosystems and their characteristics

Source: IRRI, 1996

In the Figure 3, a schematic represent the main rice ecosystems along a catena, a variety of areas and under a variety of climatic conditions, an indication of the strength of the relationship between soil and topography. It is important to note that the ecosystem irrigated rice, whose main feature is the control, at a greater or lesser degree depending on the area, of the water level in all lockers throughout the crop cycles through channels of irrigation and drainage, can actually be met at any level of this fictitious catena, provided a water supply or pump is available to enable single, double, or even triple annual crop.

Table 2: International typologies of rice classifications based on general surface hydrology

Deep-water rice, Tidal wetlands or Floating
a. Deep water (50-100 cm) b. Very deep water (>100 cm, sometime 500-600 cm) where we divided into 4 sections: i. Tidal wetlands with perennially fresh water ii. Tidal wetlands with seasonally or perennially saline water iii. Tidal wetlands with acid sulfate soils iv. Tidal wetlands with peat soils
Rainfed Lowland (0-50 cm)
a. Rainfed shallow, favorable (0-25 cm) b. Rainfed shallow, drought prone (0-25 cm) c. Rainfed shallow, drought and submergence prone (0-25 cm) d. Rainfed shallow, submergence-prone (0-25 cm) e. Rainfed medium deep, waterlogged (25-50 cm)
Irrigated rice (5-15 cm)
a. Irrigated, with favorable temperature for growing of rice (22-32 ºC) b. Irrigated, low-temperature, tropical zone c. Irrigated, low-temperature, temperate zone
Upland rice (no standing water)
a. Favorable upland with long growing season (LF) b. Favorable upland with growing season (SF) c. Unfavorable upland (risk of drought and/or acid soils) with long growing season (LU) d. Unfavorable upland with growing season (SU)

Reference: (IRRI, 1984)

This system has been adopted for rice research at IRRI, where based on two mains classes, primary are on broad area of sustained water depth and secondary are based on subdivision of water depths; the dynamic of the water regime, including the dependability of water supply; and on soil constraints in some cases.

Of course, topographical and hydrological variations, as are socio-economic in large areas and established where a major type of rice yet predominates within the agricultural system. But it does not exclude the presence of areas cultivated with a lower level of artificial, often was dominant in the past, nor that of world exploitation of the environment announcing the next crossing of a qualitatively new important step in this field.

Table 3: Principals characteristic in 4 types of rice cultivation ecosystems

Type of rice cultivation ecosystem	Upland Rice	Rainfed Lowland Rice	Irrigated Rice	Flood-prone: Rainfed lowland + Deep Water Rice and Tidal Wetlands
Land site	Plain with steeply sloping; aerobic soil	Plain with slightly sloping; bunded fields; alternating period of aerobic to anaerobic soil condition of variable frequency	Plain Slop, bunded fields with water control, shallow flooded with anaerobic soil throughout the duration of the crop growth	Plain or very gently sloping depression; ground with alternating periods of aerobic and anaerobic; salinity and toxicity in coastal areas
Hydrology	Rarely flooded during the crop cycle, the exceptional flooding	Non-continuous flooding, variable depth and duration, but submergence not exceeding 50 cm for more than 10 consecutive days	Submersion controlled shallow (5-15 cm) throughout the duration of the crop cycle required	Non-continuous submersion, variable depth and duration, but still more than 10 days of deep submergence very deep (50 to over 300 cm) during cultivation
Main culture implantation	Rice direct seeded on plowed dry soil or dibble in wet, Non puddling soil	Rice transplanted in puddled soil or direct deeded on puddle or plowed dry soil	Rice transplanted or direct seeded with germinated grains in puddled soil	Transplanted rice after paddling or dry sows after little wet soil tillage

Rice ecosystems are characterized by the natural resources of water and land, and by the adaptation of rice plant to them. Irrigated maybe fount at any point in a toposequence if controlled water delivery and drainage are available.

I.2.2.1. Upland rice cultivation

Rice grown in rainfed, naturally well-drained soil with unbunded fields without surface water accumulation is called upland rice. Riceland that are submerged for a significant part of the growing season are not suitable for upland rice, that are classified as hydromorphic are truly upland, especially those areas on higher slopes where there is no water table in the root zone. Upland or dryland rice is grown under rainfed, naturally well drained soil is bunded or unbunded fields without surface water accumulation (Khush, 1997). Some of the upland rice areas are on sloping mountainsides. The soils of upland rice fields are well drained and no flooding occurs at any time during the crop cycle, just like in the case of a crop of wheat, barley or corn. In the case of the cycle, the ascent low water table depth between upland rice fields, as in parts of South Asia, their main role is to define the plot between agricultures (Trébuil et al., 2000).

The upland agriculture in Laos recognizes the importance research for support the development of crop diversification and production intensification. With IRRI (International Rice Research Centre) and the national research program, has provided excellent research support for upland rice production. The national capacity in agricultural research has however been limited in 1998. The National Agriculture and Forestry Research Institute was established and will hopefully take a leading role in finding answers to improve upland agriculture. The program has included variety improvement, nutrient management, green manuring, plant protection and the water management is also a major constraint to upland rice production on farming system studies (Pehu, 1997).

Soil conservation, soil fertility, residue management, and water management, all strongly interdependent, are the key issues to be addressed by interdisciplinary teams consisting of socio economists, agronomists, livestock specialists, soil scientists, and hydrologists. The key issue in the transformation of the existing system to an environmentally sound, market-oriented system is not the change from rice production using slash-and-burn methods to a plantation system, but the transition from burning biomass to a system of using the biomass for mulching or livestock production. Slash-and-burn agriculture systems practiced in the hilly parts of northern Laos are in a transition phases, with a fast reduction in the fallow and a gradual increase in the cropping periods (Roder et al., 1997).

I.2.2.2. Irrigated rice cultivation

Perhaps 40 % of rice cropping system comes from irrigated areas in SE Asia as in Table 1. About 79 million hectare or 55 percentage of the world rice area is irrigated and has adequate water supply throughout the growing season (Dobermann & Fairhurst, 2000) and much of this area was rainfall supplements irrigation water. Irrigated areas with good water control are suitable for growing improved varieties with short stature and lend themselves to improved cultural practices. It may be followed during the next dry and cool season in a less intensive cultivation in water and shorter cycle climatic system in Annex 2. When the available irrigation system, based on elevation and diversion dams along the water, allows only supplemental irrigation during periods without rain in the wet monsoon and drainage of excess water possible, a single cycle irrigated rice is produced annually. By cons, when major hydraulic structures have led to the construction of dams, reservoirs, or when irrigation is based on the pumping of groundwater (frequent in South Asia) or has a level rise water in the canals to the rhythm of the beat of the tides (as in the case of the Mekong Delta), double cropping irrigated rice through a cycle in the wet season followed by another, totally dependent on the irrigation water in the dry season can be practiced by the early varieties and not seminaines photoperiodic. In some places, the functions of the level of local consumer demand or according to the comparative profitability of rice production compared to other crops, the triple annual crop settled. The main constraints currently faced by rice farmers in the irrigated ecosystem are related to:

- A cap potential in paddy yield, stagnant since the sixties, about 10-11 tons per hectare in a few more days in this dry season (with high solar radiation), and 7-8 tons per hectare in the wet season often cloudy sky
- A tendency to cap soil productivity in irrigated rice grown in intensive monoculture in many countries, often around 6 tons of paddy per hectare, which may be accompanied by a decline in productivity of other factors of production, including chemical inputs (fertilizers and pesticides)
- Low efficiency of the use of these inputs, often already applied in very high amounts (conventionally considered less than a third of the nitrogen fertilizer applied to rice is actually useful to the plant); which still tends to decrease efficiency in irrigated rice fields with very high productivity
- Inadequate drainage leading in many places, including in areas with high natural productivity and cradles green revolution in rice, such as Punjab, degradation are land salinization and alkalization
- A growing scarcity of water resources for irrigated rice outside the wet Asia, particularly in light of the increasing cross-sectorial economic competition between agriculture, industry, services and domestic consumption, due to urbanization and rapid industrialization in irrigated plains and deltas close to large cities
- A growing lack of manpower in these economically very dynamic areas, which imposes significant changes in practices (such as the abandonment of threshing operations of nurseries and transplanting the benefit of seeding sludge pre-germinated seeds) including the motor-mechanization of farming activities still remained manual
- Major losses due to pests and diseases of culture, which are responsible for the instability of yields in areas with high soil productivity, especially where an ill-reasoned and low pesticide use is still practiced.

I.2.2.3. Rainfed lowland rice cultivation

About one-fourth of the world rice area (IRRI, 2006) and one-half of the rice lands in SE Asia are rainfed lowland as in Table 1. Rainfed lowlands have a great diversity of growing conditions that vary by amount and duration of rainfall, depth of standing water, duration of standing water, flooding frequency, time of flooding, soil type and topography. Management practices vary in the rainfed lowland has five categories (Trébuil & Hossain, 2004).

Flooded rice is grown with a very imperfect control of water during a single annual cycle in the wet season, in diked lockers, generally reduced size and submerged more or less deeply (but never more than 50 cm of water for more than ten days) for only a portion of the crop cycle. In places, depending on the length of the wet season, a culture, a legume usually short-cycle seeds (mung bean, early soy, etc…) may precede or follow the cycle of the flooded rice.

Biophysical factors limiting the improvement of the flooded rice there being different, research generally distinguished by two sub-ecosystems according to the average depth of submersion. Either it is small (0-25 cm) or the sub-flooded ecosystem is characterized by a high risk of temporary water deficit during vegetative phases or flowering rice; geographical distribution and the relative importance of this sub-ecosystem. The flooding is intermediate to deep (25-50 cm) and that is when the risk of flooding in culture with generally more devastating effects than those caused by a temporary water deficit, especially if it occurs early in the crop cycle. The areas planted to rice recession are part of the flooded rice since they are also subject to a low degree of water control. Relatively uncommon, they still occupy between 140 000 and 200 000 hectares in Cambodia, and receding rice pairs with irrigation and high yielding are greater than 6 tones per hectare expanding fast in the recent years in Cambodia (in Takeo, Prey Veng). On the whole, the flooded rice provides about 18% of world rice harvest and therefore the second rice ecosystem in order of importance.

I.2.2.4. Deep-water rice cultivation and tidal wetland

About 11 million ha of low-lying lands on the river deltas of South and South-East Asia where deep water accumulates during rainy season. Rice fields located in the tropics in the depressions of large deltas or alluvial plains, between barrier beaches or in estuaries are subjected during only part of the cycle of culture, uncontrolled annual deep submergence between June and November in the northern hemisphere. It starts about 50 to 60 days after seedling emergence and exceeds a water depth various from 50 cm to more than 3 m; however, flooding occurs only during part of the growing season.

In places, the deep of the water level can reach five to six meters above the flood. Rice deep submergence is mainly located in South Asia (along the Pawn in India and the Brahmaputra in Bangladesh) and South-East (along the lower course of the Maenam Chao Phraya in central Thailand, the Mekong in Vietnam Nam and the Irrawaddy in Burma, around Tonle Sap in Cambodia, as well as along some islands of Sumatra and Borneo coast). This rice ecosystem overall marginal annually produces about 16 million tons of paddies, only about 3% of the total rice production in the globe.

Classically, three sub-ecosystems are now distinguished in these settings:

- Rice in deep submergence ("deep-water rice") to which a layer of water from 50 to 150 cm thick at least one month during the crop cycle is common;
- Floating rice ("floating rice") met in areas where flooding can reach up to 5-6 meters deep at the height of the flood;
- Rice coastal zones subject to the beat of the tides ("tidal wetland rice") can tolerate short periods of deep submergence, often in brackish water. By the salinity tolerance is one of the adjustments of the cultivated plant material.

I.2.3. Greenhouse gas and environmental assessment of paddy rice cultivation

Rice production in SE Asia simultaneously contributes to global climate change and is affected by it. However, there is a wide range of adaptation measures already being applied, and many report of the potential on rice production has in contributing to the reduction of GHG emissions globally. Adaptation and mitigation in rice production systems both have important roles to play. Farmers will need to have access to a genetically diverse range of improved crop varieties that are resilient to climate change and suited to a variety of ecosystem and farming practices. Adaptation will allow farmers to cope with climatic events, while mitigation practices will contribute to global reduction of GHG emission from rice production.

Several approaches have been developed for estimate the greenhouse gas emission from cropping systems. The GHG emission from paddy field conduct with the Intergovernmental Panel on Climate Change (IPCC) is a Guideline for National Greenhouse Gas Inventories (IPCC, 1997). IPCC has different coefficients and emission factors from the experiment in Thailand, case study in Japan and China and another countries especially in Asia (Cai et al., 2003). This report is taking an account to conduct on the flux emission to paddy rice cultivation module of Methane (CH4), Nitrous Oxide (N_2O), Nitrogen Oxide (NO), Ammonia (NH_3), Nitrates (N), Phosphorus (P) and pesticide emission to environment. Those flux emission units were calculated by adjusting the daily background emission (EFc) with scaling factor unit (Yan et al., 2003a) and others contently in the real practices or experiment on field (Thanawong et al., 2014). Total emissions were calculated by the adjusted daily emission multiplied by annual harvested areas and cultivation period of rice (120 days are consider for generating emission) due to the crop and water management (Thanawong et al., 2014).

Anaerobic decomposition of organic material in flooded rice fields produces CH_4, which escapes to the atmosphere primarily by transport through the rice plants (Takai, 1970; Cicerone & Shetter, 1981; Conrad et al., 1989; Nouchi et al., 1990). The annual amount of CH_4 emitted from a given area of rice is a function of the number and duration of crops grown, water regimes before and during cultivation period, and organic and inorganic soil amendments (Neue & Sass, 1994; Minami, 1995). Soil type, temperature, and rice cultivar also affect CH_4 emissions.

I.3. Objectives

According the rice cultivation in different typologies of South-East Asia, it has a several approach of impact assessment to environment. The main objective is to evaluate the GHG emission by the application of specific tool for those rice cultivation was involved the inventory parameters, strategies and development for conduct more facilitated on methodological guideline. Those statements lead some questions to the following for this report are:

1. Are the classical agronomy typologies adequate to represent the environmental impacts of rice cropping systems in the S-E Asia region?
2. Is the water management system of rice cropping determinant in terms of GHG emissions?
3. Is it relevant, for this purpose and in this context, to go beyond the Tier1 approach in the EX-ACT model?
4. In what extent the EX-ACT and LCA approaches are complementary?

CHAPTER II: MATERIALS AND METHODOLOGIES

II. Materials and Methodologies

II.1. Materials

Apart from soil and water pollution, consumption of energy, water and raw materials for paddy fields with different typologies are in fact claimed to be responsible for 10 to 15% of worldwide CH_4 anthropogenic emissions (Neue, 1997), thus contributing to a great extent to the global warming phenomenon. In assessing the impact of irrigation in particular on climate change by using typical approach especially IPCC method guidance, while EX-ACT and LCA are a tool base on this guidance. Firstly, this report focuses on the relevance or adaptation of these tools to the specific case of the evaluation of irrigation impacts on climate change and secondly to identify and reduce the activities that contribute the most impact where it is interesting to accompany the agriculture in the implementation of irrigation systems with less impact on environmental efficiencies.

II.1.1. EX-Ante Carbon balance Tool assessment

EX-Ante C-balance Tool is a tool developed by FAO to provide ex-ante measurements of the impact of agriculture and forestry development projects on GHG emissions and C sequestration, indicating its effects on the C balance. EX-ACT was developed to respond for a simple tool that can carry out rapid ex-ante estimations of the impact on GHG emissions and carbon sequestration from AFOLU projects where this idea started in 2008 at FAO. With funding support from the World Bank, a team at FAO developed the EX-ACT tool with technical support from the Institut de recherche pour le développement (IRD).

EX-ACT is a land-based accounting system, measuring C stocks and stock changes per unit of land, and CH_4 and N_2O emissions expressed in tCO_2-eq per ha and per year. It appraisal guides the project design process and decision-making on funding aspects, complementing the usual ex-ante economic analysis of investment projects. Above all it has the potential to support project designers to select project activities with higher benefits both in economic and climate change mitigation terms and the output could be used in financial and economic analysis. EX-ACT was designed to work at a project level but it can easily be up-scaled at programme/sector or national levels (Cerri et al., 2010). The main output of hectare of cultivation in the tool consists of the C-balance resulting from the difference between two scenarios: with and without project options.

II.1.1.1. Rice cropping system on EX-ACT's scenario

The rice cropping system is showing under diverse conditions such as irrigated, rainfed low land, rainfed upland and flood-prone rice typologies in SE Asia. There are two main production methods, dry "upland" and wet "paddy" rice, which are used according to the seasonal period and climate (center plain of rice cultivation is shown in Annex 2). Two prevailing air currents distinctly affect the rainfall pattern: the northeast (or dry) monsoon and the southwest (or wet) monsoon. The specific issue with paddy rice is the methane CH_4 emissions. Methane is formed under the anaerobic conditions in the flooded fields. To address the soil type in the rice irrigation area in SE Asia is mostly LAC soil type, but during the dry period the deep-water and low rainfed that is located in flood-prone the soil type is HAC. The average climatic is 30 °c (80 to 90 °F) where it receives more than 60 inches (1,500 millimeters) of rainfall annually, and many areas commonly receive double and even triple that amount, as conclude in the Table 4 for the project description.

Table 4: Project Description for EX-ACT module

Project Name	Irrigation on Rice Typologies in SE Asia	
Continent	Asia (Continental)	
Climate	Tropical	
Moisture regime	Moisture	
Dominant Regional Soil Type	LAC / HAC soil	
Duration of the Project (Years)	Implementation phase	1
	Capitalization phase	0
	Duration of accounting	1

II.1.2. Life Cycle Assessment framework

The environmental impacts of the agricultural sector have been raised over recent years, life cycle analyse or assessment LCA has become a common methodology to assess these potential environmental impacts. LCA is a methodology for evaluates the environmental impact of alternative rice cultivation activities such as irrigation, farming and food processing methods. It would lead to a single indicator, comprehensive review of all the impact categories using numerical factors based on value choices and each unit.

This section presents the LCA methodology which has been applied to many kinds of agricultural products including rice production system. Evaluation of environmental impacts is a primary function of LCA which is taking into account the entire life cycle of the product. This includes extraction of resources to the production of materials (cradle), components of the product itself, reuse, recycling and disposal still final end product (grave) (Guinée et al., 2002). According to ISO 14040 (2006), LCA is taking an account with four main stages on distinguish: goal and scope definition, life cycle inventory, life cycle impact assessment and interpretation of the results (Baumann & Tillman, 2004).

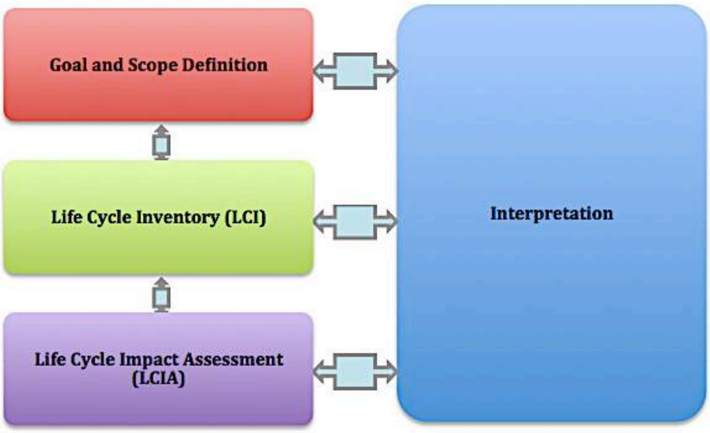


Figure 4: Phases of life cycle assessment framework
Sources: ISO 14040, 1997

i. Goal Definition and Scoping: The phase defines and describes the product, process or activity to be studied and specifies the overarching goal underlying the research, its scope and objectives. It is aimed to identify the objectives, functional unit, system boundaries, cutoff criteria, data source and framework of tier structure for AFOLU methods.

ii. Life Cycle Inventory (LCI): To build a system model according to the requirement of the goal and scope definition. LCI gives a detailed of compilation on environmental inputs (material and energy) and outputs (air, water, land or solid emission) at each stage of the life cycle. This phase identifies and quantifies energy, water, inputs and materials usage and environmental releases associated with each stage of production (e.g., air emissions, solid waste disposal, waste water discharges). This stage of LCA is critical because of the LCI results are needed to perform any type of quantitative impact assessment.

iii. Life Cycle Impact Assessment (LCIA): The third stage of LCA can be performed after LCI have been quantified and aims for quantifying the relative importance of all the environmental burdens identified in the LCI by analysing their influence on selected environmental effects. Impact assessment consists of three stages: classification, characterization and valuation. Classification is the assignment of LCI inputs and outputs impacts groupings. Characterization is the process of developing a conversion model to translate LCI and supplemental data to impact descriptors. Valuation is the assignment of the relative values or weights to different impacts allowing integration across all impact categories (Curran, 1996).

iv. Interpretation: This last phase evaluates the results of the inventory analysis and impact assessment to select the preferred product, process or service with a clear understanding of the uncertainty and the assumptions used to generate the results. As in figure 4 illustrates the LCA framework with the links between the four phases.

II.1.2.1. System boundaries and functional unit

The setting of system boundaries in LCA is a strong, delicate step that can influence the results to a great extent. If the boundary is set too narrowly, some important impacts may be undetected. If it is set too broadly, impacts other than those generated by the process of interest may be included. System boundaries, as well as input and emission categories are shown in Figure 5.

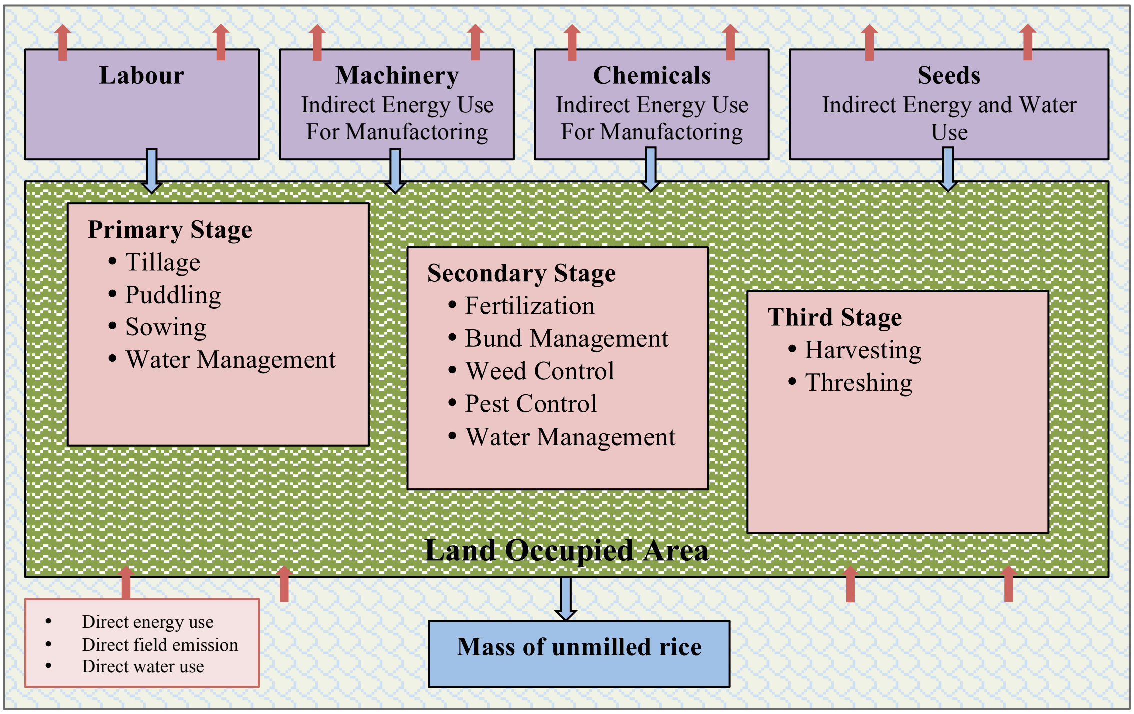


Figure 5: System boundaries for unmilled rice chain in the north and northeast of Thailand

It represents the details of agricultural process which were set up based on the interviewing with farmers in the north and northeast of Thailand. The starting of agricultural process is land preparation and followed by the method to grow Hom Mali rice. In Thailand, there are two methods to grow rice, which are transplanting and sowing (broadcasting). Before transplanting, farmers have to do the nursery which has to prepare the nursery land by tillage and then sow the rice seed, but rice seed has to be soaked in water before sowing and then wait for small rice grows up. After small rice grows, the farmers can transplant to the paddy field. Another method to grow rice is sowing; farmers no need to do the nursery. Hom

Mali rice production takes time around six months between planting and harvesting. During the growing period, to get good yields, normally farmers in Thailand need to do fertilizer application, pest management and weed management by applying fertilizers, pesticides, herbicides, fungicides, insecticides and raticides. During the growing period also release direct air emission such as methane, nitrous oxide and ammonia, as well as, emissions of phosphorus and nitrates in the water.

Based on the study in Thailand (Thanawong et al., 2014) where was apply rice as an agri-food product with the functional unit (FU) selected is 1 kg of refined rice packed and delivered to the supermarket. Overall, the performed LCA is therefore attribution and static are decided:

- The primary FU for LCA is the mass (1 kg) of raw paddy rice (unmilled) at the farm gate (approximately 15% humidity content).
- The secondary FU is 1 ha of land used for the production of raw paddy rice (unmilled) at the farm gate.

II.1.3. Evaluation of calculation procedure

Most procedures are designed to include rice cultivation for the different type of typologies and methodological complexity. The entire specific tools are based on the IPCC guidelines and follow the framework of tier structure for AFOLU methods. In range of evaluation, the direct field emission from CH_4, N_2O, NH_3 and NO are the source for emission where are account in the almost calculator assessment. In this case, most current LCA calculators with associated databases (e.g. SimaPro-Rice, Rice et al., 1997) are in the product assessment where it is private businesses to analyze impacts along a value chain and improve a product's carbon footprint. A single tool cannot be used in all situations, as each tool has its own aims such as raising awareness, reporting, project evaluation and product assessment; greater uniformity would be desirable. The ideal would be to have one set of certified tools for landscape-scale GHG emission, with module of rice typology or particular geographical situation. The modules would couple physical data to socio-economical parameters and hide irrelevant sources for the particular situation. When possible, tools designed for landscape scale should be given priority for the AFOLU sector of GHG assessment (IPCC or EX-ACT), but some farm-scale tool (LCA) may be a useful alternative.

As on each method in Table 4 are considered on different procedure of calculation but for LCA, direct field emission to air are calculated by the IPCC for CH4 and the others emission indicators are follow the model of Akiyama et al., 2005 as in equation 4. And EX-

ACT is based on IPCC guile line for finding CH_4 emission but N_2O captures by amount of rate (fertilization plan) using in kg per hectare. For more detail of IPCC calculation is on the chapter 11 of IPCC guideline, which is related to N_2O emission from managed soils and CO_2 emission from lime and urea application.

Table 5: Evaluation on calculation of rice assessment methods

Calculation for rice assessment	Direct field emission to air				Speed of assessment	Rice Typologies Practice
	CH_4	N_2O	NH_3	NO		
IPCC	x	x	o	o	xx	x
LCA*	x	x	x	x	x	x
EX-ACT	x	+	o	o	xx	xx

x : accurate on time and skills require, xx : fast and easy to use, o : none defined, + : available in some case
** reference: study developed by (Perret et al., 2013)*

II.2. Methodologies

II.2.1. Carbon dioxide (CO_2) emission

Carbon stock categories that involve transfers to the atmosphere can be converted to units of CO_2 emissions by multiplying the C stock change by -44/12. It should also be noted that not every stock change corresponds to an emission. The conversion to CO2 from C, is based on the ratio of molecular weights (44/12). The change of sign (-) is due to the convention that increases in C stocks, i.e. positive (+) stock changes, represent a removal (or 'negative' emission) from the atmosphere, while decreases in C stocks, i.e. negative (-) stock changes, represent a positive emission to the atmosphere. As in equation 1, it gives the assumption for the annual carbon stock changes for rice cultivation as a sum of changes in each stratum with the category.

$$\Delta C_{LU_i} = \Delta C_{AB} + \Delta C_{BB} + \Delta C_{DW} + \Delta C_{LI} + \Delta C_{SO} + \Delta C_{HWP}$$

(Equation 1)

Carbon stock change in annual average in difference period (stock-difference method):

$$\Delta C = \frac{(C_{t_2} - C_{t_1})}{(t_2 - t_1)}$$ (Equation 2)

Where:

ΔC_{LU_i} : Carbon stock changes for a stratum

ΔC : Annual carbon stock change in the pool, tonnes C yr^{-1}

C_{t_1} : Carbon stock in the pool at time t_2, tonnes C

C_{t_2} : Carbon stock in the pool at time t_2, tonnes C

II.2.2. Methane (CH_4) emission from rice cultivation to air

Rice production, especially from flooded rice soils, is a large source of atmospheric methane, therefore a large contributor to global warming. According to the IPCC (2007), estimates of the global emission rate from paddy fields (where CH_4 is predominant) are 60 tonnes per year. Under anaerobic conditions of submerged soils of flooded rice fields, the methane that is produced predominately escapes from the soil into the atmosphere via gas spaces that are found in the rice roots and stems, and the remainder of the methane bubbles up from the soil and/or disperses slowly through the soil and overlying flood water in Figure 6.

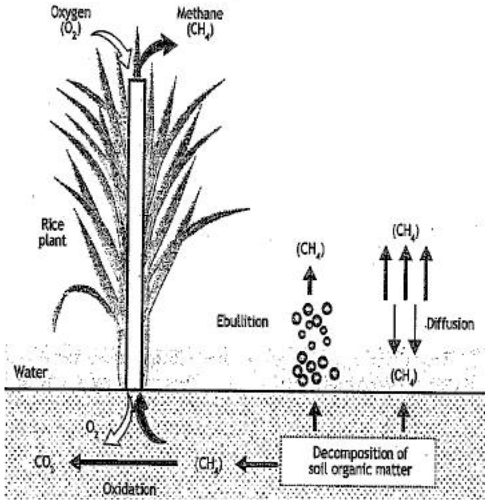


Figure 6: Dispersion of methane

Source: (Maclean et al., 2002) cited in FAO

The basic equation to estimate CH_4 emissions from rice cultivation is shown in Equation 3. It is good practice to account for this variability by disaggregating national total harvested area into sub-units (e.g., harvested areas under different water regimes). Harvested area of each sub-unit is multiplied by the respective cultivation period and emission factor that is representative of the conditions that define the sub-unit (Li et al., 2002).

$$CH_{4\,Rice} = \sum_{i,j,k}\left(EF_{i,j,k} \times t_{i,j,k} \times A_{i,j,k} \times 10^{-3}\right) \qquad \text{(Equation 3)}$$

Where:

$CH_{4\,Rice}$: Annual methane emissions from rice cultivation, $t\ CH_4 \cdot yr^{-1}$

$EF_{i,j,k}$: A daily emission factor for i, j, and k conditions, $kg\ CH_4 \cdot ha^{-1} \cdot yr^{-1}$

$t_{i,j,k}$: Cultivation period of rice for i, j, and k conditions, day

$A_{i,j,k}$: Annual harvested area of rice for i, j, and k conditions, $ha \cdot yr^{-1}$

i, j, and k : Represent different ecosystems, water regimes, type and amount of organic amendments, and other conditions under which CH_4 emissions from rice may vary

II.2.2.1. Adjusted daily emission for choosing emission and scaling factors

The different conditions that should be considered include rice ecosystem type, flooding pattern before and during cultivation period, and type and amount of organic amendments. Other conditions such as soil type, and rice cultivar can be considered about the relationship between these conditions and CH_4 emissions are available. In addition, IPCC guidelines (2006) are proposed a model for calculating daily emissions in Equation 4 should be estimated for each cropping season by taking into account as possible differences in cultivation practice (e.g., use of organic amendments, flooding pattern before and during the cultivation period).

$$EF_i = EF_c \times SF_w \times SF_p \times SF_o \times SF_{s,r} \qquad \text{(Equation 4)}$$

Where:

- EF_i : Adjusted daily emission factor for a particular harvested area
- EF_c : Baseline emission factor for continuously flooded fields without organic amendments
- SF_w : Scaling factor to account for the differences in water regime during the cultivation period
- SF_p : Scaling factor to account for the differences in water regime in the pre-season before the cultivation period
- SF_o : Scaling factor should vary for both type and amount of organic amendment applied
- $SF_{s,r}$: Scaling factor for soil type, rice cultivar, etc., if available

II.2.2.1.1. Baseline emission factor (EF_C)

EF_C refers to the following conditions in a given cropping situation for no flooded fields for less than 180 days prior to rice cultivation and continuously flooded during the rice cultivation period without organic amendments is used as a starting point. The IPCC default for EF_C is 1.30 kg CH4 $ha^{-1}day^{-1}$ (with an error range of 0.80 - 2.20), estimated by a statistical analysis of available field measurement data (Yan et al., 2005).

According to the development of region-specific emission factors and estimation of CH_4 emission from rice fields in the South-East Asia countries or based on the FAO-AEZ[2], in Table 6. For Myanmar and Thailand lie in the warm sub humid topic FAO-AEZ 2, but Thailand was classified into five regions different where are northern, northeastern, eastern, central and southern region. In Vietnam, Laos and Cambodia, are suggested as in one group in FAO-AEZ 3, the warm humid tropics *(Yan et al., 2003a).*

Table 6: Methane (CH_4) emission factors $(kg\ CH_4 \cdot ha^{-1} \cdot d^{-1})$ for various countries and regions in SE Asia

Agro Ecological Zones	Country and region		Irrigated	Rainfed	Deep-water
FAO-AEZ 2	Myanmar		2.5176	1.7058	2.88
	Thailand	Northern	2.04	1.44	
		Northeastern	3.12	2.2008	
		Central			0.744
		Eastern	1.9584	1.3824	
		Southern			
FAO-AEZ 3	Cambodia Laos Vietnam		2.3208	1.4544	1.4616

Reference: (Yan et al., 2003a)

II.2.2.1.2. Water regime during the cultivation period (SFw)

It provides default scaling factors and error ranges reflecting different water regimes. In the disaggregated case, flooding patterns can be distinguished in the form of three subcategories as shown in Table 7.

Table 7: Default CH_4 emission scaling factors for water regime during the cultivation period

Water regimes during the cultivation period relative to continuously flooded fields					
Water regime		Aggregated case		Disaggregated case	
		Scaling factor (SFw)	Error range	Scaling factor (SFw)	Error range
Upland		0	-	0	-
Irrigated	Continuously flooded	0.78	0.62 – 0.98	1	0.79 – 1.26
	Intermittently flooded – single aeration			0.60	0.46 – 0.80
	Intermittently flooded – multiple aeration			0.52	0.41 – 0.66
Rainfed and deep water	Regular rainfed	0.27	0.21 – 0.34	0.28	0.21 – 0.37
	Drought prone			0.25	0.18 – 0.36
	Deep water			0.31	Not determined

Source: (Yan et al., 2005)

[2] Agroecological zones (AEZ) based on the temperature regime that prevails during the growing season and the classification system distinguishes between tropical regions, subtropical regions with summer or winter rainfall.

Concerning the water regime during the cultivation period, the 3 categories cover the following situations:

- Irrigated – Continuously flooded: fields have standing water throughout the rice-growing season and may only dry out for harvest (end-season drainage).
- Irrigated – Intermittently flooded: fields have at least one aeration period of more than 3 days during the cropping period, no difference is made here for single or multiple aeration. The default-scaling factor proposed (0.56) is the average of the value proposed for both these cases, respectively 0.60 and 0.52.
- Rainfed and deep water: fields are flooded for a significant period of time and water regime depend solely on precipitation. It includes the following subcases:

i. Regular rainfed (the water level may rise up to 50 cm during the cropping season),

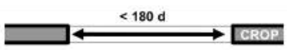
ii. Drought prone (drought periods occur during every cropping season),

iii. Deep-water rice (floodwater rises to more than 50 cm for a significant period of time during the cropping season). The scaling factor used in the RM is the aggregated value proposed for these 3 subcases (i.e. 0.27), because the factors reported for the 3 subcases are relatively similar.

Although many field experiments have been conducted to test the effectiveness of mitigation options such as intermittent irrigation (Yagi et al. 1996), crop rotation (Cai et al., 2000)and timing of rice straw application (Hatanaka et al., 1999).

II.2.2.1.3. Water regime before the cultivation period (SFp)

Table 8: Default CH_4 emission scaling factors for water regime before the cultivation period

Water regimes before the cultivation period				
Water regime prior to rice cultivation (schematic presentation showing flooded periods as shaded)	Aggregated case		Disaggregated case	
	Scaling factor (SFp)	Error range	Scaling factor (SFp)	Error range
Non flooded pre-season < 180 days 			1	0.88 – 1.14
Non flooded pre-season >180 days 	1.22	1.07 – 1.40	0.68	0.58 – 0.80
Flooded pre-season (>30 days) 			1.90	1.65 – 2.18

Reference: Yan et al., 2005

Table 7 provides default scaling factors for water regime before the cultivation period, which can be used when country-specific data are unavailable. This table distinguishes three different water regimes prior to rice cultivation, namely:

i. Non-flooded pre-season < 180 days, which often occurs under double cropping of rice;
ii. Non-flooded pre-season > 180 days, e.g., single rice crop following a dry fallow period; and
iii. Flooded pre-season in which the minimum flooding interval is set to 30 days; i.e., shorter flooding periods (usually done to prepare the soil for ploughing) will not be included in this category.

When activity data for the pre-season water status are not available, aggregated case factors can be used. It is good practice to collect more disaggregated actionable data and apply disaggregated case of SFp. In the Rice Module a Table 8 is reproduced in order to help the users in the meaning of the different water regimes before the cultivation period.

II.2.2.1.4. Organic amendments (SFo)

An equal mass basis, more CH_4 is emitted from amendments containing higher amounts of easily decomposable carbon and emissions also increase as more of each organic amendment is applied. It is good practice to develop scaling factors that incorporate information on the type and amount of organic amendment applied on compost, farmyard manure, green manure, and rice straw.

Table 9: Default conversion factor for different types of organic amendment

Organic amendment	Conversion factor (CFOA)	Error range
Straw incorporated shortly (<30 days) before cultivation	1	0.97 - 1.04
Straw incorporated long (>30 days) before cultivation	0.29	0.20 - 0.40
Compost	0.05	0.01 - 0.08
Farm yard manure	0.14	0.07 - 0.20
Green manure	0.50	0.30 - 0.60

Reference: Yan et al., 2005

Equation 5 and Table 9 present an approach to variance the scaling factor by according to the amount of different types of amendment applied. Rice straw is often incorporated into the soil after harvest. In the case of a long fallow after rice straw incorporation, CH_4 emissions in the ensuing rice-growing season will be less than the case that rice straw is incorporated just before rice transplanting (Fitzgerald et al., 2000). An uncertainty range of 0.54-0.64 can be adopted for the exponent 0.59 in Equation 5, adjusted CH_4 emission scaling factors for organic amendments.

$$SF_o = (1 + \sum_i ROA_i \times CFOA_i)^{0.59} \quad \text{(Equation 5)}$$

Where:

SF_o	:	Scaling factor for both type and amount of organic amendment applied
ROA_i	:	Application rate of organic amendment i, in dry weight for straw and fresh weight for others, $\text{tonne} \cdot \text{ha}^{-1}$
$CFOA_i$	:	Conversion factor for organic amendment i (in terms of its relative effect with respect to straw applied shortly before cultivation) as shown in Table 9

II.2.2.1.5. Soil type (SFs) and rice cultivar (SFr)

In some countries emission data for different soil types and rice cultivars are available and can be used to derive SFs and SFr, respectively. Both experiments and mechanistic knowledge confirm the importance of these factors, but large variations within the available data do not allow one to define reasonably accurate default values. It is anticipated that in the near future simulation models will be capable of producing specific scaling factors for SFs and SFr.

II.2.3. Direct Nitrous Oxide N_2O emission

Table 10: N_2O Emission from paddy rice fields

N_2O Emission From Rice Paddy Fields With Chemical or Organic Fertilizer Applied During the Cropping Season				
Water Regime	Mean	Standard Deviation	Range	
			Minimum	Maximum
BE, Baseline of N2O Emission, gN ha-1				
Continuous flooding	341	474	28	2150
Midseason drainage	993	1075	26	4416
Rain-fed, wet season	188	75	97	249
All water regimes	667	885	26	4416
EF, Emission factor of fertilizer-induced N2O Emission Factor, %				
Continuous flooding	0.22	0.24	0.003	0.69
Midseason drainage	0.37	0.35	0.02	1.16
Rain-fed, wet season	ND	ND	ND	ND
All water regimes	0.31	0.31	0.003	1.16

N_2O Emission From Rice Paddy Fields With No N Fertilizer Input During the Cropping Season				
BE, Baseline of N2O Emission, gN ha-1				
Continuous flooding	211	143	38	323
Midseason drainage	372	284	34	847
Rain-fed, wet season	ND	ND	ND	ND
All water regimes	325	258	34	847

Reference: (Akiyama et al., 2005)

Agricultural soil is a major source of nitrous oxide N_2O and it is a GHG where contributes to the destruction of stratospheric zone. As an earlier study on N_2O suggested to be negligible from the paddy fields (Smith et al., 1982). However, recently the researchers found out to suggest that rice cultivation is an important anthropogenic source of not only atmospheric methane (CH_4) but also N_2O (Cai et al. 1997). The current IPCC guidelines use a default fertilizer-induced emission factor (EF) of 1.25% of net N input (based on the unvolatilized portion of the applied N) and a background emission rate for direct emission from agricultural soil of 1 $kgNha^{-1}yr^{-1}$ (IPCC, 1997). In that guideline, rice paddy fields were not distinguished from upland fields.

Mean background N_2O emission (emission from paddy fields without N fertilizer application) during the cropping season was not significantly different between continuous flooding and midseason drainage regimes in Table 9. As with the review published reports of N_2O emissions from rice paddy fields and tried to establish a quantitative basis on which to develop national or regional emission inventories. The estimated background emission value has large uncertainty, because available measurements were very limited, especially for the fallow period, even though fallow rice fields are considered an important source of N_2O. According by Akiyama et al., 2005 compiled and analyzed data on N_2O emissions from rice fields as in Equation 6 captures that model, which failed to consider intermittent flooding conditions, with drying periods where more active nitrification-denitrification occurs, probably leading to higher N2O emissions.

$$\boldsymbol{N_2O - N = (EF \times N_f) + BE} \qquad \text{(Equation 6)}$$

Where

$\boldsymbol{N_f}$: Total N units applied through chemical fertilization, per ha, the during cropping cycle (which depending on the observation of the sampling,

$\boldsymbol{EF}$: Average fertilizer-induced emission factor,

$\boldsymbol{BE}$: Average baseline N-N_2O emission.

Conversion N_2O-N of emission to N_2O emission for reporting purposes is performed by using the following equation:

$$\boldsymbol{N_2O = N_2O - N \times \frac{44}{28}} \qquad \text{(Equation 7)}$$

II.2.4. Nitric Oxide (NO) emission

With fewer experimental in approach for background NO emission, as not enough field measurements were available to derive a better estimate and investigated literature on NOx

(Yan et al., 2003b). This results in a fertilizer-induced emission factor of 0.13% for all N fertilizing units applied and average baseline emission for an annual emission of 0.57 $kgNha^{-1}yr^{-1}$. Capture by model as in Equation 8 (Yan et al., 2003b), which failed to consider intermittent flooding conditions, with drying periods where more active nitrification-denitrification occurs, probably leading to higher NOx emissions.

$$\boldsymbol{NO - N\, kg.ha^{-1} = [EF \times Nf\,] + [BE \times \frac{D}{365}]} \qquad \text{(Equation 8)}$$

Where:

$\boldsymbol{Nf}$	:	Total N units applied through chemical fertilization, per ha, during the cropping cycle) which depending on the observation of the sampling
$\boldsymbol{EF}$	:	Average fertilizer-induced emission factor, 0.0013
$\boldsymbol{D}$	:	Actual duration of cropping season
$\boldsymbol{BE}$	:	Average baseline N-NO emission over 365 days, 0.57 $kgNha^{-1}yr^{-1}$

II.2.5. Ammonia (NH_3) emission

Yan et al., 2003b focused literature analysis of urea-induced NH_3 emissions since urea is the most common chemical fertilizer used by farmers in South and South-East Asia. Timing and mode of application have a strong influence on volatilization rate. As proposed by Yan et al., 2003b, urea-induced NH_3 emissions depend upon timing and mode of application, as follows: volatilization forms 20% of application when incorporation is performed in land preparation, 36% when urea is top-dressed (broadcast) after transplantation/seedling, 12% when application occurred at the time of panicle initiation. Urea-induced emissions followed by the model shown in Equation 9.

$$\boldsymbol{NH_3 - N \cdot kg \cdot ha^{-1}_{urea} = CF \times \{(U_{inc} \times 0.2) + (U_{trans} \times 0.36) + \left(U_{pan} \times 0.12\right)\}} \qquad \text{(Equation 9)}$$

Where:

$\boldsymbol{CF}$	:	Conversion factor from N-Urea to Urea, 0.46
$\boldsymbol{U_{inc}}$	:	Mass of urea applied and incorporated in soil at land preparation time
$\boldsymbol{U_{trans}}$	:	Mass of urea broadcast (top-dressed) after transplantation/seedling time, during the vegetative phase
$\boldsymbol{U_{pan}}$	:	Mass of urea broadcast (top-dressed) around the panicle initiation stage

CHAPTER III: RESULTS AND DISCUSSION

III. Results and Discussion

III.1. Results of EX-ACT

III.1.1. Upland rice cultivation

Upland rice cultivation is considered to be like an upland and rainfed cereal area. Since it is an annual crop and therefore must be treated in the "Annual Module". According to the IPCC and in the management option, the emissions are influenced only by the loss or gain of soil organic carbon. Upland rice is a sustainable agricultural land management practices that does not only help to improve land productivity, but it also conserves existing soil carbon levels and lead to further carbon sequestration within the five major types of practices for upland rice cultivation.

This project is located in the warm and dry area (Laos' Climatic area) and the rate of soil carbon sequestration is shown in Table 11 of the management practice in the field. The residue biomass is 10 tons of dry matter per hectare for burning in tier 1 (IPCC, 2007). Crop residue management can influence the capacity of soil to receive, store and release water and nutrients (Unger et al., 1988).

Table 11: Annual mitigation potential of selected sustainable land management practices used in EX-ACT, considering only CO_2 effect in Warm Moist Area

Default IPCC calculation: Tier 1			
Practices	**Description**	**Rate of soil Carbon Sequestration in warm moist area**	**Residues/Biomass available for burning**
		Only CO2 (tCO_2-eq/ha/yr)	**(t Dry Matter per ha)**
Improved agronomic practices	Using improved varieties, extending crop rotations, increasing crop residues	0.88	10
Nutrient management	Using fertilizers efficiently through, micro dosing or adjustments of product, timing, placement and rate of application	0.55	
Tillage/residues management	No-till or minimum tillage, improved residue retention rates on fields	0.7	
Water management	The application of irrigation measures	1.14	
Manure application	Use of animal and green manures	2.79	

Reference: IPCC, 2007 in EX-ACT

An average value of 10 t MS/ha of residues is too high for rice. Another aspect is that a representative mitigation potential is determined as the maximum potential of all selected management practices. This approach is very conservative and supposed to be the best choice because there is evidence in the literature that some measures are not adding value when applied simultaneously. Those default values are not specific for cereal, but are proposed to be generic of the majority of annual production, and must be adapted to the species.

Table 12: Upland Rice results on default IPCC calculation in Tier 1

Default IPCC calculation: Tier 1							
Management Practice	**Mitigation Potential CO_2**		**CO_2 Total Balance**	**N_2O**	**CH_4**	**Total Emission (tCO2-eq)**	
	CO_2-sc	**CO_2-eq***				**per ha**	**per kg**
Without Residue/Biomass burning = 0 t MS/ha, *Tier 1a*							
Traditional	0.00	0.00	0.00	0.00	0.00	0.00	0.00E+00
Improved agronomic practices	-0.88	0.00	-0.88	0.00	0.00	-0.88	-2.20E-04
Nutrient management	-0.55	0.00	-0.55	0.00	0.00	-0.55	-1.38E-04
Tillage/residues management	-0.70	0.00	-0.70	0.00	0.00	-0.70	-1.75E-04
Water management	-1.14	0.00	-1.14	0.00	0.00	-1.14	-2.85E-04
Manure application	-2.79	0.00	-2.79	0.00	0.00	-2.79	-6.98E-04
All	-2.79	0.00	-2.79	0.00	0.00	-2.79	-6.98E-04
With Residue/Biomass burning = 10 t MS/ha, *Tier 1b*							
Traditional	0.00	0.62	0.62	0.17	0.45	1.25	3.14E-04
Improved agronomic practices	-0.88	0.62	-0.25	0.17	0.45	0.37	9.36E-05
Nutrient management	-0.55	0.62	0.07	0.17	0.45	0.70	1.76E-04
Tillage/residues management	-0.70	0.62	-0.07	0.17	0.45	0.55	1.39E-04
Water management	-1.14	0.62	-0.51	0.17	0.45	0.11	2.86E-05
Manure application	-2.79	0.62	-2.16	0.17	0.45	-1.53	-3.84E-04
All	-2.79	0.62	-2.16	0.17	0.45	-1.53	-3.84E-04

CO_2-sc*:* *Soil CO_2 change,* ***CO_2-eq*:*** *CO_2 emitted from burning*

Based on the result in Table 12 of tier 1a (without burning residue) and 1b (with burning residue), the carbon sequestration from manure application is higher than the other practices. For the water management, tillage or residue management, nutrient management and improve agronomic practice are different from 25 to 40 percentage comparable to manure application of the carbon sequestration. Thus, it must clearly show that along the upland rice cropping management are very important for carbon sequestration for considering the urgency on soil moisture, rotational, nutrient and organic C conservation.

According to the case study in upland rice cultivation in Laos (Roder, 2001), on the effect of residue management and fallow length on weeds and rice yield, they quantify the amount of burning the dry matter of rice in 1.9 and 2.4 tons per hectare for retreatment the crop production. The result shown in Table 13, the traditional upland rice management emits GHG emission while the other practices sequestrate the carbon. We can conclude that the results of emission are related to the different tiers of using residue/biomass available for burning which is very important to improve rather than to practice in traditional upland rice.

Table 13: Upland Rice results on default IPCC calculation in Tier 2

IPCC calculation: Tier 2							
Management options	**Mitigation Potential CO_2 CO_2-sc**		**CO_2 Total Balance CO_2-eq**	**N_2O**	**CH_4**	**Total Emission (tCO2-eq)**	
	CO_2-sc	**CO_2-eq***				**per ha**	**per kg**
With Residue/Biomass burning = 2.4 ton/ha, *Tier 2a*							
Traditional	0.00	0.15	0.15	0.04	0.11	0.30	7.53E-05
Improved agronomic practices	-0.88	0.15	-0.73	0.04	0.11	-0.58	-1.45E-04
Nutrient management	-0.55	0.15	-0.40	0.04	0.11	-0.25	-6.22E-05
Tillage/residues management	-0.70	0.15	-0.55	0.04	0.11	-0.40	-9.97E-05
Water management	-1.14	0.15	-0.99	0.04	0.11	-0.84	-2.10E-04
Manure application	-2.79	0.15	-2.64	0.04	0.11	-2.49	-6.22E-04
All	-2.79	0.15	-2.64	0.04	0.11	-2.49	-6.22E-04
With Residue/Biomass burning = 1.9 ton/ha, *Tier 2b*							
Traditional	0.00	0.12	0.12	0.03	0.09	0.24	5.96E-05
Improved agronomic practices	-0.88	0.12	-0.76	0.03	0.09	-0.64	-1.60E-04
Nutrient management	-0.55	0.12	-0.43	0.03	0.09	-0.31	-7.79E-05
Tillage/residues management	-0.70	0.12	-0.58	0.03	0.09	-0.46	-1.15E-04
Water management	-1.14	0.12	-1.02	0.03	0.09	-0.90	-2.25E-04
Manure application	-2.79	0.12	-2.67	0.03	0.09	-2.55	-6.38E-04
All	-2.79	0.12	-2.67	0.03	0.09	-2.55	-6.38E-04

CO_2-sc*:* *Soil CO_2 change,* ***CO_2-eq*:*** *CO_2 emitted from burning*

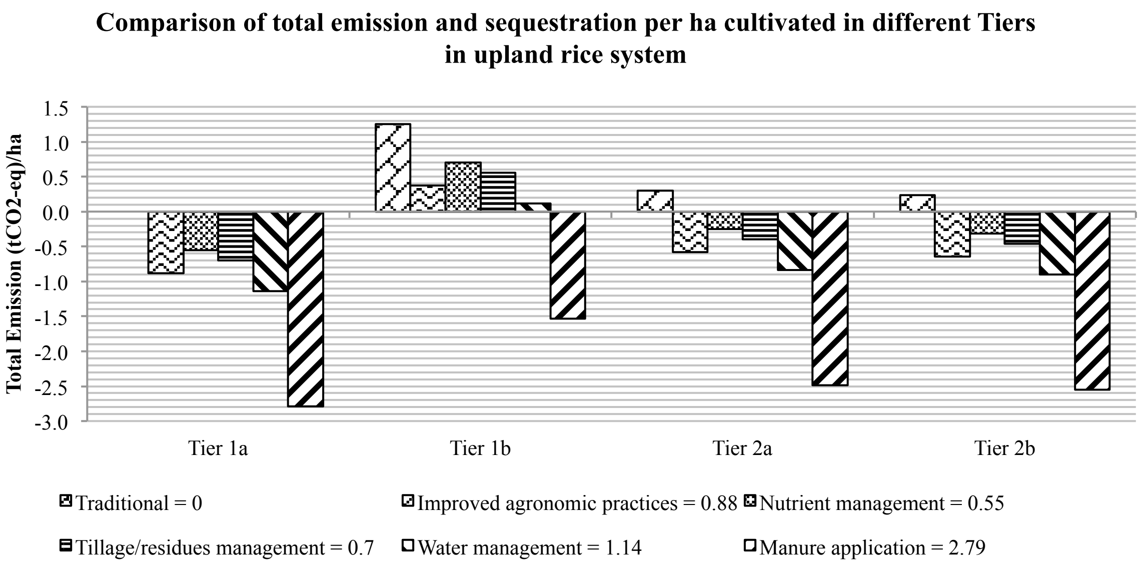


Figure 7: Direct field emission and sequestration from upland rice cultivation of different Tiers per ha cultivated

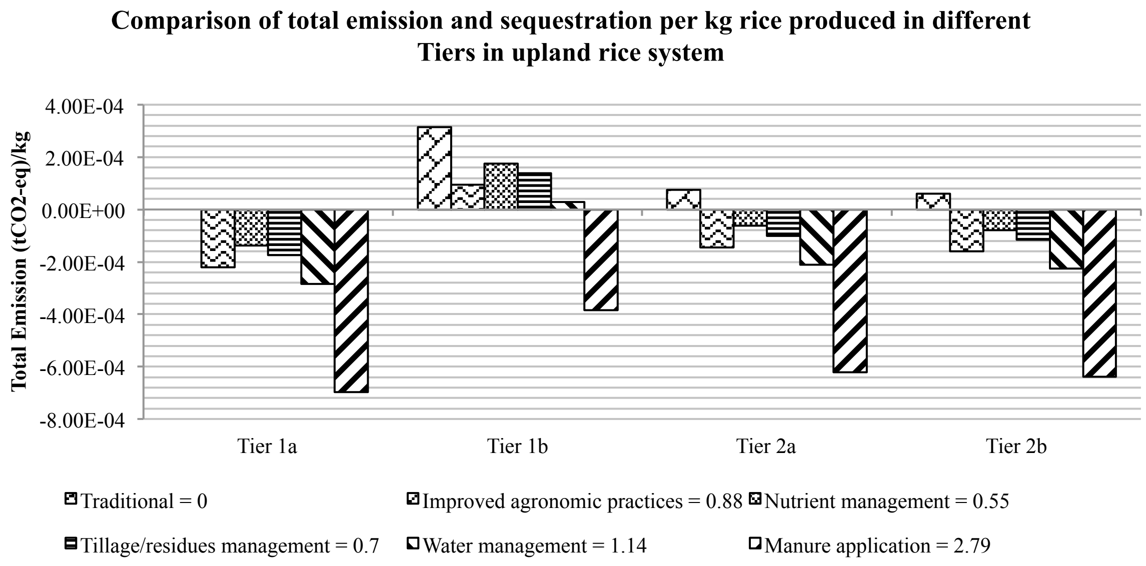


Figure 8: Direct field emission and sequestration from upland rice cultivation of different Tiers per kg rice produced

As shown in Figure 7 and 8, upland rice areas have different typologies and different tiers. For the tier 1b is the indicator that emits GHG the most to the atmosphere even though they have the same manure application for sequestered as others. It is a key message that even the amount of burning the residue is required to be precise, but upland rice is needed development.

III.1.2. Irrigated rice cultivation

Irrigated rice is a type of rice cultivation very common for developing countries. It prevents leakage of water resources and assigns the proper amount of water to increase yield crop. It is generally expected that irrigated agriculture will have to be extended in the future in order to feed the world's growing population (Döll, 2002). However, it is not yet found whether there will be enough water available in short and long term depending on the climate change. Several irrigation approaches based on cropping season, water regime and technical method within available in the field's operation. Irrigated area is further divided into the irrigated wet season when rainfall is supplemental with irrigation water and irrigated dry season when rainfall is very low and irrigation is the primary source of water supply. The rice growing season is divided into two main seasons are raining and dry season, so the rice crop is variable on the growing periods. Yields during the dry season are higher than during the wet season due to higher incoming solar radiation.

According to the schematic in Figure 3, rice has major ecosystems. Irrigated rice was suggested and summarized to 6 different groups as in Table 14, based on irrigated rice area of case study in the Cambodia region by Dr. Stephane Boulakia and Dr. Florent Tivet and study developed by Dr. Sylvian R. Perret in Thailand on rice production in the North-eastern 2010 evaluated 45 diverse rice cropping systems, with three rice systems, namely wet-season rainfed, wet-season irrigation and dry-season irrigation systems (Thanawong et al., 2014). Based on this, a wide-ranging performances and impacts were observed, despite cropping practices were relatively homogeneous. The differences between the systems were originated mostly from the difference in yield potential and also the water management.

Table 14: Summary of Irrigated Rice in different countries as reference

Cultivation Description	Water Regime of cultivation period		Country Reference
	Before	During	
Rice crop production during wet season			
Irrigated Rice 1	Non flooded preseason <180 d	Continuously flooded	Thailand
Irrigated Rice 2	Flooded preseason >30 d		Vietnam
Irrigated Rice 3	Non flooded preseason >180 d	Intermittently flooded - Single Aeration	Cambodia, Laos, Myanmar
Irrigated Rice 4	Non flooded preseason <180 d		Thailand
Irrigated Rice 5	Non flooded preseason <180 d	Intermittently flooded - Multiple Aeration	Cambodia, Thailand
Rice crop production during dry season			
Irrigated Rice 1	Non flooded preseason <180 d	Continuously flooded	Thailand, Cambodia
Irrigated Rice 2	Flooded preseason >30 d		Cambodia, Vietnam
Irrigated Rice 4	Non flooded preseason <180 d	Intermittently flooded - Single Aeration	Thailand, Vietnam
Irrigated Rice 5	Non flooded preseason <180 d	Intermittently flooded - Multiple Aeration	Thailand, Myanmar
Irrigated Rice 6	Flooded preseason >30 d		Vietnam, Thailand

Table 15: Irrigated rice cultivation and water regime description

Cultivation Description	Water Regime and default value of scaling factor on EX-ACT, IPCC 2006				
	During the cultivation Period		SF_W	Before the cultivation period	SF_P
Irrigated Rice 1	Irrigated - Continuously flooded		1.00	Non flooded preseason <180 days	1.00
Irrigated Rice 2				Flooded preseason >30 days	1.90
Irrigated Rice 3	Irrigated - Intermittently flooded	Single Aeration	0.60	Non flooded preseason >180 days	0.68
Irrigated Rice 4*				Non flooded preseason <180 days	1.00
Irrigated Rice 5*		Multiple Aeration	0.52	Non flooded preseason <180 days	1.00
Irrigated Rice 6				Flooded preseason >30 days	0.68

** They are in the same scale for tier 1 in EX-ACT*

Therefore, the different 6 types of irrigated rice cultivation that are related to their function of water regime before and during the cultivation period and where it has an organic amendment type is straw brunt for 1 unit with 5.5 tonnes (default value in IPCC) of rate residues over biomass available for burning. There have two types of water regime during the cultivation of irrigated like a continuously and intermittently flood, while there also have different three types of water regime before cultivation, such as non-flooded preseason >180 days, non-flooded preseason <180 days and flood preseason >30 days. The study was accumulated a default value of the area is in 1 hectare per each type of rice as describe on Table 15. As in EX-ACT, irrigated rice was classified in two categories as continuously and intermittently flooded and so for the type 4 and 5 were put in one type for tier 1 (as the default).

In the Table 16, the results show within two different growing periods for wet and dry seasons respond to the climatic in Asia of 150 and 100 days, respectively. The different value between those two seasons for cultivation period is about 33 percentages, as they have the same emission factor for procedure management of crop and water regime.

The total emission is taken an account of CH_4 and N_2O by an equivalent to CO_2: CH_4 is 21 and N_2O is 310 of official (1st period 2008-2012). Correspondingly, the scaling factors for water regime in rice-growing season and water status in preseason are varied with the real situation. As the result of Table 16, IR 2 must be able to derive the amount of the total GHG emission and different type of organic amendment in EX-ACT. These results can be used for the development of national and regional emission inventories.

Table 16: Irrigated rice result on default IPCC calculation in Tier 1

Default IPCC calculation: Tier 1							
Cultivation Description	**EF**	**Wet season**			**Dry season**		
		Total Emission	**Total Emission (tCO_2-eq)**		**Total Emission**	**Total Emission (tCO_2-eq)**	
		kg CH_4/ha	**per ha**	**per kg**	**kg CH_4/ha**	**per ha**	**per kg**
Irrigated Rice 1	1.30	195.00	4.10	3.15E-04	130.00	2.73	2.10E-04
Irrigated Rice 2	2.47	370.50	7.78	5.99E-04	247.00	5.19	3.99E-04
Irrigated Rice 3	0.49	74.26	1.56	1.20E-04	49.50	1.04	8.00E-05
Irrigated Rice 4	0.72	109.20	2.29	1.76E-04	72.80	1.53	1.18E-04
Irrigated Rice 5	0.72	109.20	2.29	1.76E-04	72.80	1.53	1.18E-04
Irrigated Rice 6	1.38	207.48	4.36	3.35E-04	138.32	2.90	2.23E-04

$EF= EF_c \times EF_W \times EF_P \times EF_O$ *: Adjusted daily emission factor in kg CH_4/ha/day,* ***EF_c=1.3 kg CH_4/ha/day*** *: Baseline emission factor of each country in reference,* ***SF_W****: Scaling factor in water regime during the cultivation,* ***SF_P****: Scaling factor in the pre-season before cultivation period,* ***SF_O=1****: Scaling factor of organic amendment applied,*

For the most impact of GHG emission to atmosphere is the IR 2, which it is continuously flood with preseason > 30 days and their emission factor is 2.47 kgCH_4/ha/day while the straw brunt management for organic amendment in the wet season have the emission in tCO_2-eq is 7.78 per ha and 5.99E-04 per kg, and in the dry season is 5.19 per ha and 3.99E-04 per kg of rice produce in the emission in tCO_2-eq.

Table 17: Results of Irrigated Rice Type 2 for different organic amendment type in Tier 1

Default IPCC calculation: Tier 1 on Irrigate Rice Type 2								
Organic Amendment Type, SF_O		**EF**	**Wet season**			**Dry season**		
			Total Emission	**Total Emission (tCO_2-eq)**		**Total Emission**	**Total Emission (tCO_2-eq)**	
			kg CH_4/ha	**per ha**	**per kg**	**kg CH_4/ha**	**per ha**	**per kg**
Straw burnt	1.00	2.47	370.50	7.781	5.99E-04	247.00	5.19	3.99E-04
Straw exported	1.00	2.47	370.50	7.781	5.99E-04	247.00	5.19	3.99E-04
Straw incorporated shortly (<30d) before cultivation	3.01	7.45	1117.91	23.476	1.81E-03	745.27	15.65	1.20E-03
Straw incorporated long (>30d) before cultivation	1.75	4.34	650.32	13.657	1.05E-03	433.55	9.10	7.00E-04
Compost	1.15	2.85	427.60	8.980	6.91E-04	285.07	5.99	4.60E-04
Farm yard manure	1.40	3.46	518.91	10.897	8.38E-04	345.94	7.26	5.59E-04
Green manure	2.18	2.47	370.50	7.781	5.99E-04	247.00	5.19	3.99E-04

EF= EF_c x EF_W x EF_P x EF_O *: Adjusted daily emission factor in kg CH_4/ha/day,* ***EF_c=1.3 kg CH_4/ha/day*** *: Baseline emission factor of each country in reference,* ***SF_W=1*** *: Scaling factor in water regime during the cultivation,* ***SF_P=1.9*** *: Scaling factor in the pre-season before cultivation period,* ***SF_O****: Scaling factor of organic amendment applied with rate of organic amendment 5.5 ton/ha,*

In the Table 17, the results show the calculation of EX-ACT in type 2 of irrigates rice in the organic amendment within different 7 types. Straw incorporated shortly < 30 days before cultivation has the same value of emission to straw burnt, by comparing to straw incorporated long > 30 days, compost, farmyard manure and green manure before cultivation are different 67, 43, 13 and 29 percentages, respectively. For this reason, the irrigated type 2 was flooded precision greater than 30 days and continuously flooded in water regime of cultivation has the most emit to the atmosphere, prior to it was a straw incorporated long greater than 30 days, it has double impact emission in CO_2 equivalent while it is very important.

As keeping the same calculation procedure, the amount of emission factor baseline EF_C were estimated by each countries in SE Asia and the national level coefficient for Myanmar, Thailand, Cambodia, Laos and Vietnam, where it stands on tier 2. In the Table 18, it shows the result of 1 hectare per rice description and the same the water regime as before cultivation but for water regimes during cultivation were suggested to intimately flood in multiple aeration is 0.52 and in single aeration is 0.60, (Yan et al., 2003). The emission factor per ha and day of country in Myanmar is 2.5176, Thailand is 2.3728 and Cambodia, Laos and Vietnam is 2.3208 as tier 2a, tier 2b and tier 2c, respectively. Efforts were made in order to regionalize rice fields by climate and soil properties, and to incorporate the effect of organic input and water regime on emission.

Table 18: Irrigated rice result on default IPCC calculation in Tier 2

Default IPCC calculation: Tier 2						
Cultivation Description	**SF_w**	**SF_P**	**EF**	**Total Emission**	**Total Emission (tCO2-eq)**	
				kg CH_4/ha	**per ha**	**per kg**
Tier 2a (Myanmar) with methane emission factor EF_c= 2.5176* kg CH_4/ha/day						
Irrigated Rice 1	***1.00***	1.00	2.52	377.64	7.93	6.10E-04
Irrigated Rice 2		1.90	4.78	717.52	15.07	1.16E-03
Irrigated Rice 3	***0.60#***	0.68	1.03	154.08	3.24	2.49E-04
Irrigated Rice 4		1.00	1.51	226.58	4.76	3.66E-04
Irrigated Rice 5	***0.52#***	1.00	1.31	196.37	4.12	3.17E-04
Irrigated Rice 6		1.90	2.49	373.11	7.84	6.03E-04
Tier 2b (Thailand) with methane emission factor EF_c= 2.3728* kg CH_4/ha/day						
Irrigated Rice 1	***1.00***	1.00	2.37	355.92	7.47	5.75E-04
Irrigated Rice 2		1.90	4.51	676.25	14.20	1.09E-03
Irrigated Rice 3	***0.60#***	0.68	0.97	145.22	3.05	2.35E-04
Irrigated Rice 4		1.00	1.42	213.55	4.48	3.45E-04
Irrigated Rice 5	***0.52#***	1.00	1.23	185.08	3.89	2.99E-04
Irrigated Rice 6		1.90	2.34	351.65	7.38	5.68E-04
Tier 2c (Cambodia, Laos and Vietnam) with methane emission factor EF_c= 2.3208* kg CH_4/ha/day						
Irrigated Rice 1	***1.00***	1.00	2.32	348.12	7.31	5.62E-04
Irrigated Rice 2		1.90	4.41	661.43	13.89	1.07E-03
Irrigated Rice 3	***0.60#***	0.68	0.95	142.03	2.98	2.29E-04
Irrigated Rice 4		1.00	1.39	208.87	4.39	3.37E-04
Irrigated Rice 5	***0.52#***	1.00	1.21	181.02	3.80	2.92E-04
Irrigated Rice 6		1.90	2.29	343.94	7.22	5.56E-04

$EF = EF_c \times EF_W \times EF_P \times EF_O$: Adjusted daily emission factor in kg CH_4/ha/day, EF_c: Baseline emission factor of each country in reference, SF_W: Scaling factor in water regime during the cultivation, SF_P: Scaling factor in the pre-season before cultivation period, SF_O=1: Scaling factor of organic amendment applied,
*Reference: * Yan et al., 2003*
 # Disaggregated case in Yan X. et al., 2005

The organic amendment management on each tier is very important to estimate the GHG emission from the irrigated rice cultivation. As in the Figure 9 and 10, for continue flood preseason > 30 days is the most significant emission factor in the atmosphere while it is suggested to the country where have twice or triple of rice cultivation per year. It was 35 percent compared to the other organic amendment type and the large amount in Myanmar (tier 2a) is 15 tCO2-eq while the other is 14 tCO2-eq in tier 2b and 2c. Moreover, the value of tier 1 comparing to others was a half different based on to their emission factor baseline for each country. Modern irrigated rice varieties and improved cultivation techniques have had the greatest impact on increasing the emission while the productivity of rice is rising, too.

Most of the irrigated areas are planted to improved varieties and more fertilizer and other inputs are used than in other ecologies.

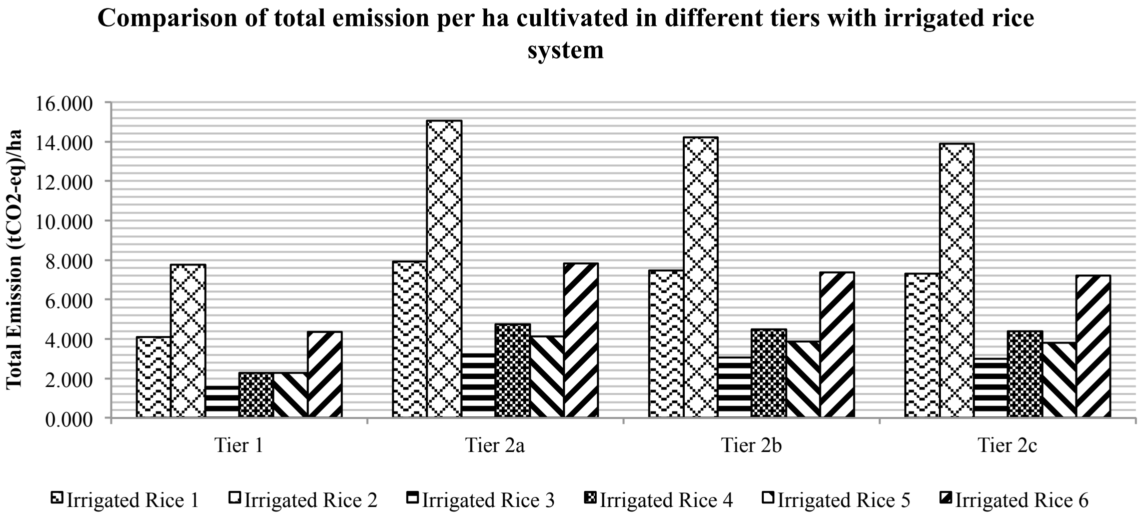


Figure 9: Direct field emissions form irrigated rice cultivation of different Tiers per ha cultivated

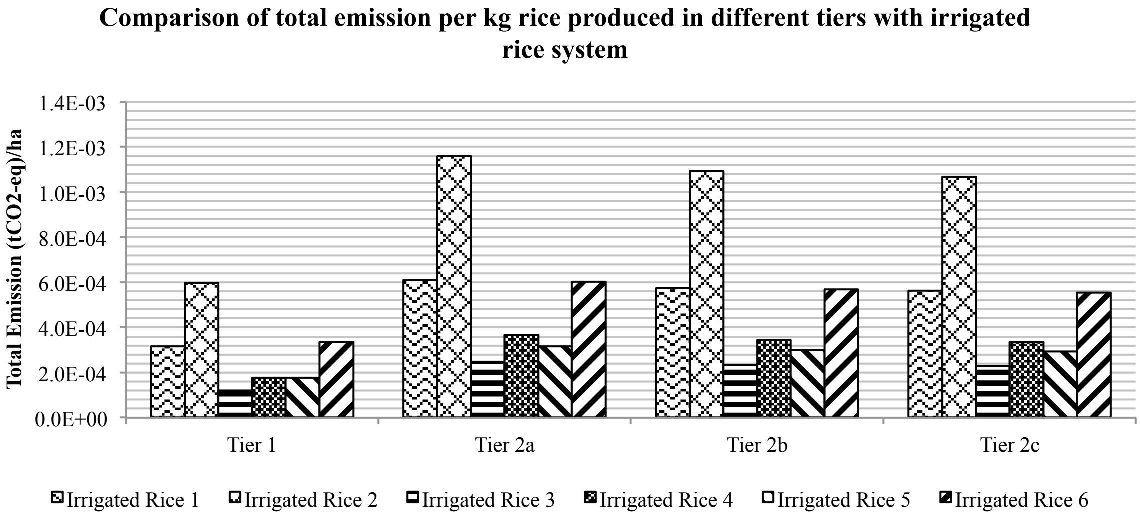


Figure 10: Direct field emissions form irrigated rice cultivation of different Tiers per kg rice produced

III.1.3. Rainfed Low Land and Deep-Water rice cultivation

The rainfed Low Land and Deep-Water rice or tidal wetlands were considered as flood prone rice cultivation. This system is low-lying extremes of rainfed lowlands characterized by level to slightly sloping fields often lying in slight depressions or basins. The main crop may be flooded to a depth of 50 to 300 centimeters for 10 or more consecutive days. At the flood-prone extreme, there is a particularly complex relationship between flooding pattern and crop development.

Table 19: Summary of Rainfed and Deep-water rice cultivation in different countries

Cultivation Description	Rice Description in EX-ACT	Water Regime of cultivation period		Country Reference
		Before	During	
Rice crop production during wet season				
Rainfed Low Land Rice 1	Rainfed and Deep-water 1	Non flooded pre-season <180 days	Drought prone	Cambodia, Laos, Myanmar, Thailand
Deep-water Rice 1	Rainfed and Deep-water 2	Flooded pre-season >30 days	Deep water and Regular rainfed	Cambodia, Laos, Myanmar, Vietnam
Rice crop production during dry season				
Rainfed Low Land Rice 1	Rainfed and Deep-water 1	Non flooded pre-season <180 days	Drought prone	Cambodia, Laos, Myanmar, Thailand
Rainfed Low Land Rice 2		Non flooded pre-season <180 days	Regular rainfed	Cambodia, Laos, Myanmar, Thailand
Deep-water Rice 1	Rainfed and Deep-water 2	Flooded pre-season >30 days	Deep water	Cambodia, Vietnam

During the year, this system divides the rice cultivation in two different ecosystems and soil types, such as in flood period, it was a HAC soil type (Alisols) but when the flood are more shallow during the dry season the rainfed lowland becomes LAC soil type for regular rainfed and drought prone. As reference on each country on this typology, the rice has two main different types and summarized in the Table 19. Deep water paddies, the least used way of growing rice in Vietnam, are mainly located in the Mekong Delta (Sandin, 2005).

Table 20: Rainfed and deep water rice result on default IPCC calculation in Tier 1a

Default IPCC calculation: Tier 1a (with straw exported)								
Rice description	Before the cultivation period	EF	Wet season			Dry season		
			Total Emission	Total Emission (tCO2-eq)		Total Emission	Total Emission (tCO2-eq)	
			kg CH_4/ha	per ha	per kg	kg CH_4/ha	per ha	per kg
Rainfed and Deep-water 1	Non flooded preseason <180 days	0.35	52.65	1.11	1.58E-04	35.10	0.74	5.67E-05
Rainfed and Deep-water 2	Flooded preseason >30 days	0.66	100.03	2.10	3.00E-04	66.69	1.40	1.08E-04

$EF= EF_c \times EF_W \times EF_P \times EF_O$ *: Adjusted daily emission factor in kg CH_4/ha/day,* ***EF_c=1.3 kg CH_4/ha/day*** *: Baseline emission factor of each country in reference,* ***SF_W=0.27*** *: Scaling factor in water regime during the cultivation,* ***SF_P= 1 for type 1 and =1.9 for type 2****: Scaling factor in the pre-season before cultivation period,* ***SF_O=1*** *: Scaling factor of organic amendment applied*

For the flooded rice in crop production in EX-ACT tool model, the rainfed low land and deep-water rice were set in one type of water regime during cultivation period where the SF_W

= 0.27. A default of 1.3 kg of CH_4 per hectare was utilized for rainfed and deep-water rice field without organic amendment and with a preseason water status of short drainage. The amount of the emission was taken account in 1 hectare for each rice description and with straw export for organic amendment (SF_O=1) as a base value to compare all different scenario in that typology of rice. For the result in Table 20, it describes about the different of growing period for rice crop season in wet season for 150 days and dry season for 100 days, which it was different between 33 percentages.

According to Yan et al., 2005, the rainfed and deep-water rice are separate study because the water regime during the cultivation period is 0.25 for drought prone, 0.28 for regular rainfed rice and 0.31 for deep-water rice. So the amount of the GHG emission should be divided as on the result in Table 21, its calculation based on SF_E is 1.30 and SF_O = 1.00 in straw burning management. In this rice cultivation, we estimated into different types, like the first one is drought prone, second is regular rainfed in low land and the third is deep-water rice. The greater number is DR 2 with regular rainfed is 2.41 tCO2-eq/ha and 4.82E-04 tCO_2-eq/kg.

Table 21: Result of rainfed low land and deep-water rice in Tier 1b for SFw

Default IPCC calculation: Tier 1b (SF_w by Yan et al., 2005)									
Rice description	**SF_w***	**SF_P***	**EF**	**Wet season**			**Dry season**		
				Total Emission	**Total Emission (tCO2-eq)**		**Total Emission**	**Total Emission (tCO2-eq)**	
				kg CH_4/ha	**per ha**	**per kg**	**kg CH_4/ha**	**per ha**	**per kg**
Rainfed Low Land Rice 1	***0.25***	1.00	0.33	48.75	1.02	1.46E-04	32.50	0.68	5.25E-05
Rainfed Low Land Rice 2	***0.28***	1.00	0.36	54.60	1.15	1.64E-04	36.40	0.76	5.88E-05
Deep Water Rice 1	***0.31***	1.90	0.77	114.86	2.41	4.82E-04	76.57	1.61	1.24E-04

EF= EF_c x EF_W x EF_P x EF_O *: Adjusted daily emission factor,* ***EF_c=1.3 kg CH_4/ha/day*** *: Baseline emission factor of each country in reference,* ***SF_W****: Scaling factor in water regime during the cultivation,* ***SF_P****: Scaling factor in the pre-season before cultivation period,* ***SF_O=1*** *: Scaling factor of organic amendment applied*
*Reference: * Disaggregated case in Yan X. et al., 2005*

In the Table 22, the study focus on organic amendment type where it is significant to GHG emission where there are straws burnt, straw exported, straw incorporated shortly < 30 days before cultivation, Straw incorporated long > 30 days before cultivation, Compost, Farm yard manure and Green manure. As there were suggested to separate between rainfed and deep water rice, so the result comprises the organic amendment management. The amount of emission of the straw incorporated shortly < 30 days before cultivation was still higher which is the same on the irrigated rice typology. This is very command to low region surrounding the Mekong basin such as in Cambodia and Vietnam where is essential to rice crop production activity per year. The highest values are of 6.34 tCO2-eq/ha and 9.06E-04 tCO2-eq/kg for the straw incorporated shortly < 30 days before cultivation.

Table 22: Results of Deep Water Rice 2 for different organic amendment management, SF_O

Default IPCC calculation: Tier 1 on Deep Water Rice 2								
Organic Amendment type, SF_O		**EF**	**Wet season**			**Dry season**		
			Total Emission	**Total Emission (tCO_2-eq)**		**Total Emission**	**Total Emission (tCO_2-eq)**	
			kg CH_4/ha	**per ha**	**per kg**	**kg CH_4/ha**	**per ha**	**per kg**
Straw burnt	1.00	0.67	100.04	2.10	3.00E-04	66.69	1.40	1.08E-04
Straw exported	1.00	0.67	100.04	2.10	3.00E-04	66.69	1.40	1.08E-04
Straw incorporated shortly (<30d) before cultivation	3.01	2.01	301.84	6.34	9.06E-04	201.22	4.23	3.25E-04
Straw incorporated long (>30d) before cultivation	1.75	1.17	175.59	3.69	5.27E-04	117.06	2.46	1.89E-04
Compost	1.15	0.77	115.45	2.42	3.46E-04	76.97	1.62	1.24E-04
Farm yard manure	1.40	0.93	140.11	2.94	4.20E-04	93.40	1.96	1.51E-04
Green manure	2.18	1.45	218.19	4.58	6.55E-04	145.46	3.05	2.35E-04

$EF= EF_c \times EF_W \times EF_P \times EF_O$ *: Adjusted daily emission factor in kg CH_4/ha/day ,* ***EF_c=1.3 kg CH_4/ha/day*** *: Baseline emission factor of each country in reference,* ***SF_W= 0.27*** *: Scaling factor in water regime during the cultivation,* ***SF_P= 1.9*** *: Scaling factor in the pre-season before cultivation period,* ***SF_O****: Scaling factor of organic amendment applied with rate of organic amendment 5.5 ton/ha,*

There have a several emission factors were development of region-specific and estimation of methane emission from rice fields in the East, South-East and South Asia countries (Yan et al., 2003b). The different EF_C values are related to finding the emission factor per hectare per day on different countries in SE Asia, regarding on rainfed rice and deep water in Myanmar, Thailand and Cambodia, Laos and Vietnam were separated by their agro ecological zones.

All emission factors are shown in Table 23, the calculation is based on the same scenario of the water regime during and after cultivation and organic amendment as in tier 1, but it is different on methane emission EF_C in kg CH_4/ha/day for various countries. The result accumulates the amount of emission on Myanmar are higher than the other two (tier 2b and 2c) for the flooded preseason greater than 30 days, where it is 5.34 and 1.5 tCO_2-eq/ha for rainfed and deep-water rice in respectively. In Thailand is 1.38 and 1.48 tCO_2-eq/ha for rainfed and deep-water rice in respectively and for Cambodia, Laos and Vietnam is 2.71 and 1.28 tCO_2-eq/ha for rainfed and deep water rice, respectively. It is very important to understand the region of EF_C value (for tier 2) of methane emission factors in ton or kilogram per hectare per day because the emission affected by the properties functional of the each county where it relates to their agro ecological and topography zone.

Table 23: Rainfed Low Land rice and Deep Water rice results of Tier 2

Default IPCC calculation: Tier 2							
Rice description	**EF_C***	**SF_w#**	**SF_P**	**EF**	**Total Emission**	**Total Emission (tCO_2-eq)**	
					kg ha/day	**per ha**	**per kg**
Tier 2a (Myanmar) with methane emission factor in kg CH_4/ha/day							
Rainfed Low Land Rice 1	***1.7058***	***0.25***	1.00	0.43	63.97	1.34	1.92E-04
Rainfed Low Land Rice 2		***0.28***	1.00	0.48	71.64	1.50	2.15E-04
Deep Water Rice 1	***2.8800***	***0.31***	1.90	1.70	254.45	5.34	7.63E-04
Tier 2b (Thailand) with methane emission factor in kg CH_4/ha/day							
Rainfed Low Land Rice 1	***2.6564***	***0.25***	1.00	0.42	62.79	1.32	1.88E-04
Rainfed Low Land Rice 2		***0.28***	1.00	0.47	70.32	1.48	2.11E-04
Deep Water Rice 1	***0.7440***	***0.31***	1.90	0.44	65.73	1.38	2.76E-04
Tier 2c (Cambodia, Laos and Vietnam) with methane emission factor in kg CH_4/ha/day							
Rainfed Low Land Rice 1	***1.4544***	***0.25***	1.00	0.36	54.54	1.15	1.64E-04
Rainfed Low Land Rice 2		***0.28***	1.00	0.41	61.08	1.28	1.83E-04
Deep Water Rice 1	***1.4616***	***0.31***	1.90	0.86	129.13	2.71	5.42E-04

$EF = EF_c \times EF_W \times EF_P \times EF_O$: Adjusted daily emission factor in kg CH_4/ha/day, EF_c: Baseline emission factor of each country in reference in kg CH_4/ha/day , SF_W : Scaling factor in water regime during the cultivation, SF_P: Scaling factor in the pre-season before cultivation period, $SF_O=1$: Scaling factor of organic amendment applied

*Reference: * Yan X. et al., 2003*

 # Disaggregated case in Yan X. et al., 2005

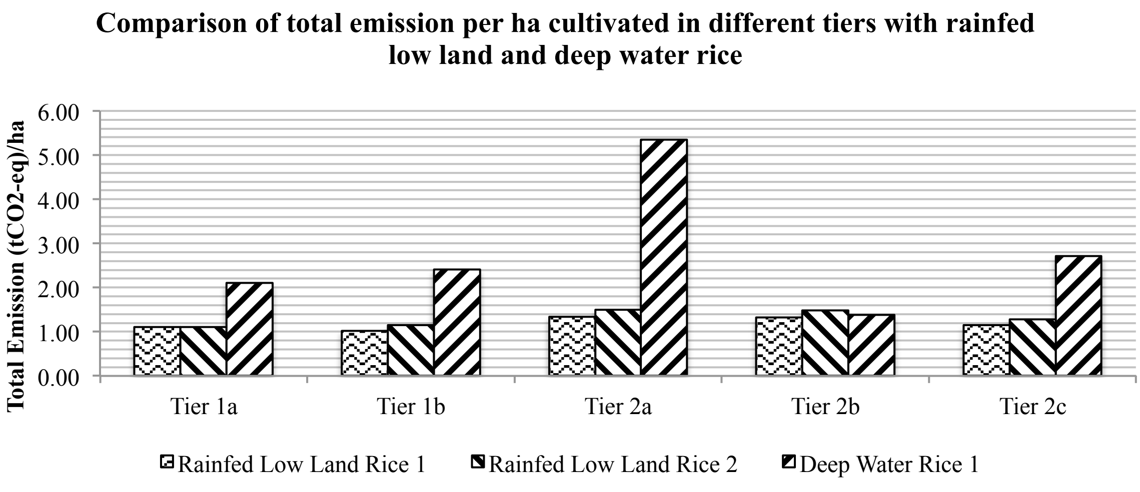


Figure 11: Direct field emission from rainfed low land and deep water rice cultivation of different Tiers per ha cultivated

The total GHG emission of rainfed low land and deep water rice cultivation are different according to the water regime before cultivation and the national level of different tiers of emission factor in different country for running in IPCC calculation on EX-ACT. As in Figure 11 and 12, each bars present the different tiers such as for adjust to default on IPCC to taken an account of deep water with SF_W in 0.31 and regular rainfed is 0.28 (Yan et al., 2005). The amount of emission for flooded preseason greater 30 days in deep-water rice of tier 2a is most significant on the rice ecosystems in Myanmar (5.34 per ha and 7.63E-04 per kg of tCO2-eq).

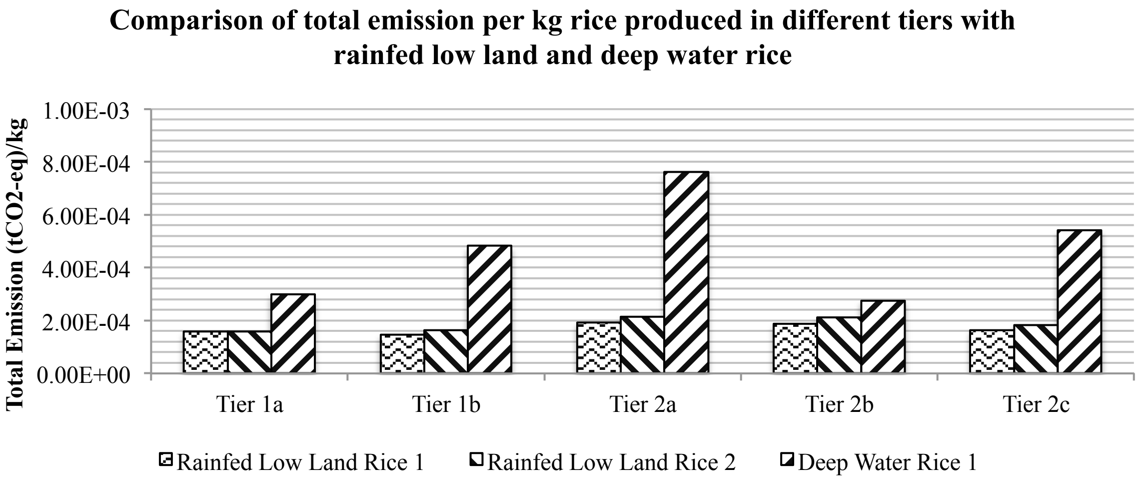


Figure 12: Direct field emission from rainfed low land and deep water rice cultivation of different Tiers per kg rice produced

III.2. Results of LCA

III.2.1. Production factors and performance of rice cultivation in SE Asia

Study developed by Perret et al., 2013 on rice production in the North-eastern Thailand in 2010 evaluated 45 diverse rice cropping systems according to three systems, namely wet-season rain-fed, wet-season irrigation, and dry-season irrigation systems. According to the authors, a wide-ranging performances and impacts were observed, despite cropping practices were relatively homogeneous. The differences among the systems were originated mostly from differences in yield, which were largely impacted by water supply.

In the Figure 13 shows the cropping calendar in the paddy field of Lam Sieo Yai basin. In wet season of rainfed and irrigated systems, there are two main varieties of rice grown (Kao Dok Mali 105 and RD6 Varieties) and in the dry season with limited time and water, farmers normally grows Hom Mali rice with RD15 variety. This study considered Kao Dok Mali 105 and RD 15 which are the main varieties of rice in wet and dry seasons, respectively. These three varieties are normally used in this study area. There is specific to both in rainfed and irrigated systems in Lam Sieo Yai basin where farmers also grow eucalyptus on the bund of paddy field. The eucalyptus can be sold to wood pulp companies, which produce paper from eucalyptus pulp.

<table>
<tr><th>Month</th><th>June</th><th>July</th><th>August</th><th>September</th><th>October</th><th>November</th><th>December</th><th>January</th><th>February</th><th>March</th><th>April</th><th>May</th></tr>
<tr><td rowspan="3">Rainfed system</td><td colspan="6">Hom Mali rice (Kao Dok Mali 105 Variety)</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="7">Glutinous rice (RD6 Variety)</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="12">Eucalyptus</td></tr>
<tr><td rowspan="4">Irrigated system</td><td colspan="6">Hom Mali rice (Kao Dok Mali 105 Variety)</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="7">Glutinous rice (RD6 Variety)</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td colspan="5">Hom Mali rice (RD15 Variety)</td></tr>
<tr><td colspan="12">Eucalyptus</td></tr>
</table>

Figure 13: Cropping calendar in the paddy field of Lam Sieo Yai basin (Northeast of Thailand)

According to the discussion with farmers in the North of Thailand, SFw factor of 1 (continuous flooding) is applied during wet-season in both Rw and Iw systems, but 0.52 is applied into Id systems (intermittent flooding). On the other hand SFw of 0.52 is applied to all rice cropping systems in the Northeast region. The farmers in the North region said that in the wet season, there is more than enough rainfall and irrigation water to ensure continuous flooding. It is different in the Northeast where surface water and rainfall is often not enough for irrigation. Indeed, rainfall data from both regions show that Northern region benefits about twice more precipitation than Northeast.

Thailand is under rainfed conditions where rice is usually grown only once a year in the wet season, where the monsoon rain is the single source of water supply for rice cultivation. Rainfed conditions refer to the uncontrolled supply of water to paddy fields, where water is kept for rice cropping by controlled drainage. Less than 20 percent of the area is under irrigated conditions where rice can be grown not only in the wet season, but also in the dry season when irrigation water supply is available (Sommut et al., 2004). Irrigation refers to the purposive, organized, infrastructure-supported supply of water to paddy fields, with controlled drainage. Rice production in Isaan is mostly lowland rainfed (75%) and shows low yields (2.5t/ha). The Central Plain area is mostly irrigated (80%) and shows more intensified production patterns, with higher yields (3.5t/ha), yet far from regional records of more than 4 in Vietnam or China. Thailand’s lower yields also refer to the choice of growing low-yielding, high quality, high value varieties (Jasmine rice for domestic and export use).

Table 24: Production factors and performance in selected rice cropping system

Production factors and performances	Reference unit	Quantity (reference unit/ ha of cultivated Hom Mali Rice)			Quantity (reference unit/1 kg of paddy Hom Mali Rice)		
		Rw	Iw	Id	Rw	Iw	Id
Land	Ha	2375.00	2625.00	2188.00	1.00	1.00	1.00
Labour	man hr.	358.49	219.69	133.00	6.63	11.95	16.45
Fertilizer	kg of fertilizer	3.80	3.82	3.18	625.00	687.50	687.50
Pesticide	kg of active matter	468.44	356.84	188.98	5.07	7.36	11.58
Total water	m^3	0.38	0.37	0.30	6285.00	7026.00	7256.00
Green water	m^3	0.38	0.42	1.87	6285.00	6285.00	1172.00
Blue water	m^3	9500.00	3.55	0.36	0.25	740.54	6084.00
Total energy	MJ	0.14	0.13	0.10	17281.00	19530.00	19783.00

***Rw**: wet-season rainfed low land rice, **Iw**: wet-season irrigated rice, **Id**: dry-season irrigated rice*

Table 25: Direct field emissions from the paddy field

Direct emission		Reference unit	Quantity (reference unit/ ha of cultivated Hom Mali Rice)			Quantity (reference unit/1 kg of paddy Hom Mali Rice)		
			Rw	Iw	Id	Rw	Iw	Id
Emission to air	Methane CH_4	kg CH_4	180.36	416.22	385.90	7.59E-02	1.59E-01	1.76E-01
	Nitrous Oxide N_2O	kg $N\text{-}N_2O$	0.74	0.76	0.77	3.10E-04	2.90E-04	3.50E-04
	Nitric Oxide NO	kg N-NO	0.43	0.45	0.46	1.80E-04	1.70E-04	2.10E-04
	AmmoniaNH_3	kg $N\text{-}NH_3$	53.22	53.42	53.41	2.24E-02	2.04E-02	2.44E-02
Emission to water	Nitrates NO_3^-	kg N	96.24	101.75	103.69	4.05E-02	3.88E-02	4.74E-02
	Phosphorus P	kg P	36.88	45.31	48.00	1.55E-02	1.73E-02	2.19E-02
	Glyphosate	g	76.71	127.84	127.78	3.23E-02	4.87E-02	5.84E-02
	Calcium carbonate	g	79.80	79.80	132.81	3.36E-02	3.04E-02	6.07E-02
	Isoprocarb	g	140.60	14.07	23.41	5.92E-02	5.36E-03	1.07E-02
	Metaldehyde	g	0.00	78.23	78.11	0.00	2.98E-02	3.57E-02
Emission to soil	Glyphosate	g	76.71	127.84	127.78	3.23E-02	4.87E-02	5.84E-02
	Calcium carbonate	g	79.80	79.80	132.81	3.36E-02	3.04E-02	6.07E-02
	Isoprocarb	g	140.60	14.07	23.41	5.92E-02	5.36E-03	1.07E-02
	Metaldehyde	g	0.00	78.23	78.11	0.00	2.98E-02	3.57E-02

***Rw**: wet-season rainfed low land rice, **Iw**: wet-season irrigated rice, **Id**: dry-season irrigated rice*

In the Table 25 reports the direct field emissions that were calculated. Emissions to air proved relatively homogeneous across all three systems, with the notable exception of methane emissions. Rw systems emit a median amount of 76 g CH_4 per kg of paddy rice, compared with 159 g and 176 g for Iw and Id systems, respectively. Lower CH4 emissions in rain-fed conditions relate first to the water regime in the pre-season before the cultivation period (non-flooded conditions for more than 180 days) and second to the management of organic residues (incorporated more than 30 days before cultivation). CH_4 emission figures broadly concur with those of the IPCC (2006), which reports that approximately 120 g of CH_4

are released into the atmosphere for each kg of rice produced; however, our results reveal significant local differences based on cropping systems and water management practices. With regards to emissions to water, Id systems systematically emit more nitrates, phosphates, and agro-chemicals per both functional units, on account of the overall lower productivity of chemical inputs.

Table 26: Environmental impact indicators in selected of rice-cropping system per ha cultivated

Impact Indicator		Reference unit	Quantity (reference unit/ ha of cultivated Hom Mali Rice)		
			Rw	Iw	Id
Global warming potential	GWP_{100}	kg CO_2-eq	7054.00	12784.00	12141.00
Eutrophication Potential	EP	kg PO_4-eq	178.00	208.00	217.00
Acidification Potential	AP	kg SO_2-eq	104.00	106.00	107.00
Ozone Depletion Potential	ODP	mg CFC-11-eq	168.00	177.00	180.00
Freshwater Aquatic Ecotoxicity	FWAE	kg 1.4-DB eq	656.00	195.00	812.00

Rw*: wet-season rainfed low land rice,* ***Iw****: wet-season irrigated rice,* ***Id****: dry-season irrigated rice*

Table 27: Environmental impact indicators in selected of rice-cropping system per kg rice produced

Impact Indicator		Reference unit	Quantity (reference unit/1 kg of paddy Hom Mali Rice)		
			Rw	Iw	Id
Global warming potential	GWP_{100}	kg CO_2-eq	2.97	4.87	5.55
Eutrophication Potential	EP	kg PO_4-eq	0.08	0.08	0.10
Acidification Potential	AP	kg SO_2-eq	0.04	0.04	0.05
Ozone Depletion Potential	ODP	mg CFC-11-eq	7.10E-02	6.80E-02	8.20E-02
Freshwater Aquatic Ecotoxicity	FWAE	kg 1.4-DB eq	0.28	0.30	0.37

Rw*: wet-season rainfed low land rice,* ***Iw****: wet-season irrigated rice,* ***Id****: dry-season irrigated rice*

Table 26 and 27 report the environmental impacts for selected impact categories, per ha occupied for cultivation and per kg of unmilled rice produced, respectively. Overall, LCIA confirms the results related to direct field emissions and resource-related results of the techno-economic analysis. On a land use basis (Table 26), GWP100 is markedly lower in rain-fed systems compared to irrigated systems, Iw showing the highest impact. Differences in CH4 emissions were previously discussed (straw incorporation and water management during pre-cultivation times) and explain this result. In all other impact categories, Rw systems systematically show lower impacts per ha than Iw and Id systems, with the latter having the highest impacts. However, AP, ODP and total water use are of the same magnitude across systems; yet, water use remains appreciably lower in Rw systems.

The results showed the low performances and high impacts of dry-season irrigated systems, since they require mostly blue water, while the two other systems rely primarily on green water. Besides, the dry-season irrigated systems require more energy, labor, fertilizers, pesticides, and ultimately yield lower production. When impacts are expressed per mass of paddy rice produced (Table 27), the impacts of Id systems are even higher than those of the two other systems due to the lower yields. GWP100 becomes higher in Id systems (5.55 kg CO2-eq) compared to Iw systems (4.87). Rw systems remain the least impacting with 2.97 kg CO2-eq.

III.3. Discussion

III.3.1. Comparison LCA and EX-ACT

Table 28: Different emissions of LCA and EX-ACT on each type of rice cultivation

Factor effecting the emissions	Emission Scaling Factor on LCA			Emission Scaling Factor on EX-ACT		
1. Agroecological zone	Lam Sieo Yai Basin (Northeast)			Lam Sieo Yai Basin (Northeast)		
2. Cropping Season	Wet Season		Dry Season	Wet Season		Dry Season
3. Cropping System	Rainfed	Irrigated		Rainfed	Irrigated	
Default Baseline Emission factor	***3.12***			***3.12***		
3.1. Water Regime during the cultivation period	Intermittent Flooding (multiple aeration)			Intermittent Flooding (multiple aeration)		
	0.52			***0.28***	***0.52***	
3.2. Water Regime before the cultivation period	Non Flooded Preseason > 180 days	Non Flooded Preseason < 180 days		Non Flooded Preseason > 180 days	Non Flooded Preseason < 180 days	
	0.68	***1***		***0.68***	***1***	
4. Organic Amendments	Straw > 30 days	Straw < 30 days		Straw > 30 days	Straw < 30 days	
4.1. Conversion Factor	0.29	1		0.29	1	
4.2. The Application Rate	2.5			2.5		
4.3. Scaling Factors for Organic Amendments	***1.379***	***2.094***	***2.094***	***1.379***	***2.094***	***2.094***
Adjusted Daily Emission Factor	**1.522**	**3.397**	**3.397**	**0.819**	**3.397**	**3.397**
Yield	**2375**	**2625**	**2188**	**2375**	**2625**	**2188**
Methane CH4 kg CH4/ha	180.34	416.28	385.96	97.11	416.28	385.96
Methane CH4 (tCO2-eq)/ha	3.79	8.74	8.11	2.04	8.74	8.11
Nitrous Oxide N2O (tCO2-eq)/ha	0.23	0.24	0.24	0.16	0.16	0.16

To compare the global warming potential of the two treatments, N_2O and CH_4 emissions are given in CO_2 equivalents that means related to the global warming potential. As in the Table 28, the comparison between LCA and EX-ACT are using total emission in tCO_2-eq per hectare cultivated and per kg rice produced. Those tool are based on the same emission factor on study area (EF=3.12 kgCH_4/h/day for Lam Sieo Yai, Northeast of Thailand). As a consequence, both approaches gave same levels of GHG emission, while it was expected on cross-validation. N_2O emissions are different in 30 percentages between LCA and EX-ACT but compared to CH_4, they are not significant to consider on GHG emission.

III.3.2. Interest of LCIA midpoint on the environmental impact indicators

The constraints in the life cycle impact assessment LCIA phase between midpoint versus endpoint modeling were estimated by category selection, classification, characterization and human health effects. For instance, in the table 26 and 27 show the environmental impact indicators in selected rice-cropping system per hectare cultivated and per kilogram rice produced. On a land use basis, the GWP100 is markedly different between rain-fed and irrigated system, Iw showing the highest impact. Those values conduct with process is emitting greenhouse gases, the increase of GHG in the atmosphere may contribute to global warming and the processes that result in the discharge of the excess nutrient into bodies of water may lead to eutrophication.

The environmental impact indicators are global warming potential for a 100-year time horizon (GWP100), eutrophication (EP), acidification (AP), ozone depletion (ODP) and freshwater aquatic Ecotoxicity (FWAE). These impact categories were choses based upon their widespread use in agricultural LCA studies, allowing for comparison. Report to other crops on database of AGRIBALYSE database v1.2, the most important indicator for taking account is GWP while the ODP and FWAE are not considered for impact value compare with other crop as shown in Annex 14. For the scale studies on EP and AP are located on regional thus impact value chain are also not considered because it should also reflect study goal and stakeholder values of a long term and for a whole worldwide.

III.3.3. Sensibility analyze on EX-ACT

III.3.3.1. Choice of emission and scaling factor on each Tiers

In Tier 2, it can define as the baseline management according to the prevailing conditions found in their respective country and determine country-specific emission factors. It can use the same methodological approach as Tier 1 but applies emission and stock change factors that are based on country- or region-specific data. Country-defined emission factors are more appropriate for the climatic regions, land-use system and livestock categories in that country.

In case where country-specific scaling factors are not available, default-scaling factors can be used. For instance, the amounts of GHG emission and carbon sequestration are really different in double proportion in both of cultivated area and crop production with emission factor (tier-2), except in rainfed lowland systems.

III.3.3.2. Evaluated the water management in upland rice area

Many of those practices (Table 11) in upland rice area, where is a filed never flooded for a significant period of time, may increase crop yields and thus generate higher residues with positive effects in terms of mitigation (because of increased C biomass and soil C stocks). Within increasing available water in the root zone through water management can enhance biomass production, increase the amount of aboveground and root biomass returned to the soil, and improve soil organic C concentration. For example, irrigation can have an impact on soil inorganic C stocks and fluxes, but the direction and magnitude depends on the source and nature of irrigation water. In arid and semi-arid regions, gypsum ($CaSO_4$.2H2O) amendments can lead to an increase in soil inorganic C stocks depending on the amount of Ca^{2+} that replaces Na^+ on soil colloids, relative to reaction with bicarbonate and precipitation of calcite ($CaCO_3$). However, these changes can cause gains or losses of C in this pool depending on site-specific conditions and the amount attributable to the activity can be small.

III.3.3.3. Typologies of rice in South-East Asia adequate on IPCC

The IPCC guidelines for compiling national inventories of greenhouse gas emissions (IPCC, 1997) distinguish between rice fields that are permanently flooded and those with unstable flooding regime. Based on the result along all the categories of rice system, there are adequate to give the different catena to IPCC. For instance, the following terminology for rice growing environments recognizes several criteria that affect rice production practices and varietal requirements. Factors considered in naming the environments are water regime (deficit, excess, or optimum), drainage (poor or good), temperature (optimum or low), soils (normal or problem), and topography (flat or undulating).

Rainfed low land and deep-water rice are suggested in different consideration type for EX-ACT. Rainfed rice fields fall under the latter category, while deep-water rice is characterized by long flooding periods. Based on the figure 3, the rainfed lowland is normally in the type of flooded area in form of watershed but it have two different phenomena of drought risk and flood-prone in hydromorphic plain, while the deep-water rice are all most flood for a whole period of time.

III.3.3.4. Functional Units for GHG emission accounting

The results may be expressed as a net value (emissions–removals) or as both values and are given in tons of CO_2 equivalent per year, per project, per unit area or per unit of production. The simplest reporting unit for landscape-scale GHG assessment is the quantity of GHG expressed in CO_2 equivalent per ha. However, this unit is not suitable for livestock production systems and is not associated with the production level of the area.

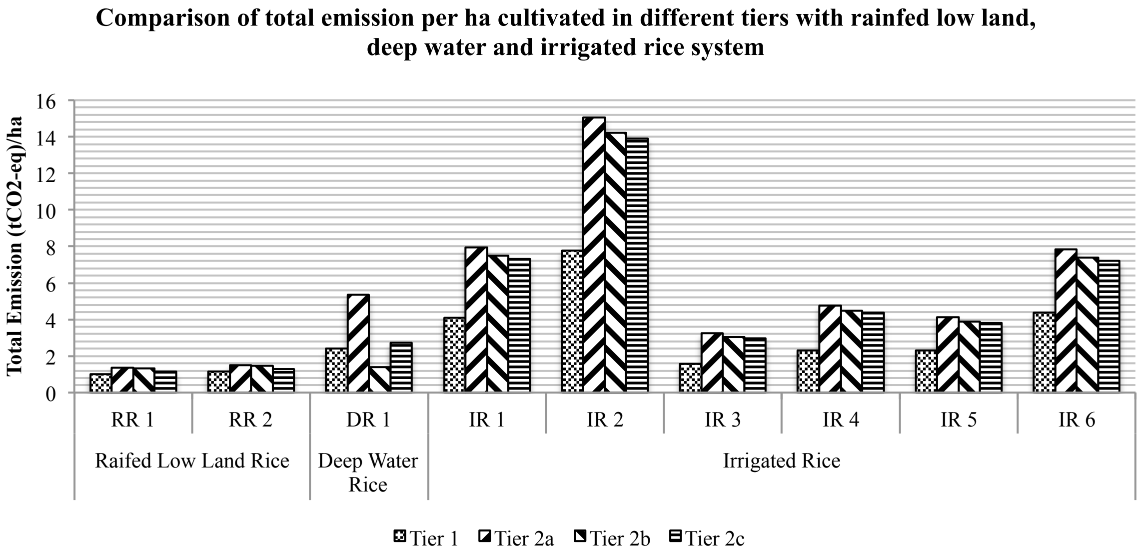


Figure 14: Direct field emissions along rice cultivation with different ecosystems types and Tiers per ha rice cultivated

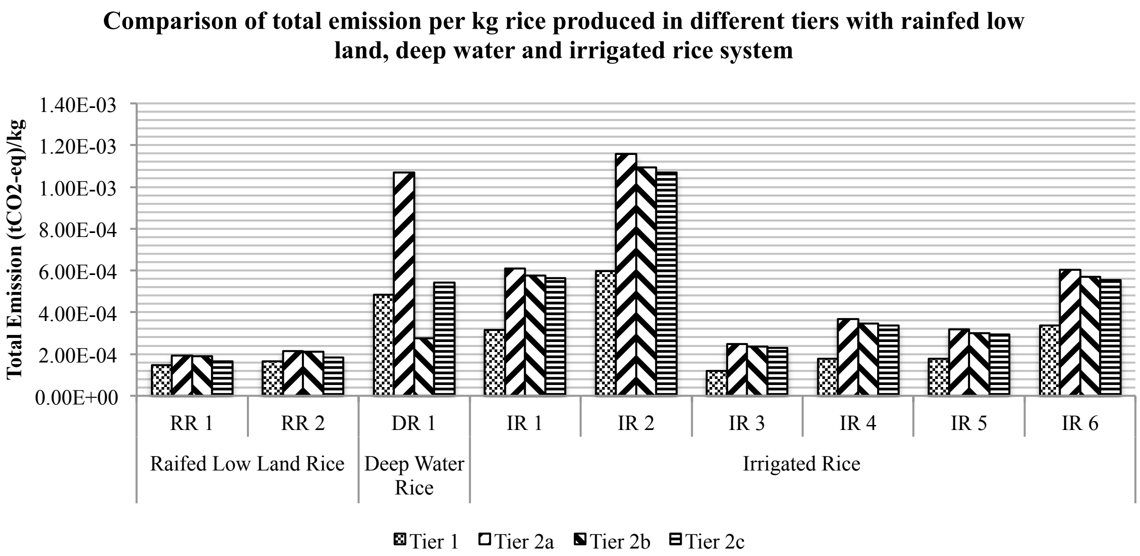


Figure 15: Direct field emissions along rice cultivation with different ecosystems types and Tiers per kg rice produced

The comparison between rice typologies' result (rainfed lowland, deep-water and irrigated rice) on the Figure 14 and 15, it is very important for looking per kilogram rice produced because the amount of emission compensate with the yield product. For instant, the highest emission rate on irrigated rice is 0.11 tCO2-eq/ton and on deep-water rice is 0.04 tCO2-eq/ton, while the paddy yield potential in irrigated rice is 12 to 13 and in deep-water is 4 to 5 ton per hectare.

Table 29: Student's T-test analysis on environmental impacts of each rice typologies

Indicators	p-value			
	Total emission per hectare cultivated		Total emission per kg rice produced	
RR1 & IR2	0.0005	***	0.0008	***
RR2 & IR2	0.0005	***	0.0009	***
DR1 & IR2	0.0020	***	0.1176	*
IR1 & IR2	0.0187	**	0.0187	**
IR3 & IR2	0.0011	***	0.0011	***
IR4 & IR2	0.0025	***	0.0025	***
IR5 & IR2	0.0017	***	0.0017	***
IR2 & IR2	0.0171	**	0.0171	**

IR: *Irrigated Rice,* ***RR:*** *Rainfed low land Rice,* ***DR:*** *Deep-water Rice*
** low significant difference at p≤0.1*
*** significant difference (p≤0.05)*
**** highly significant difference (p≤0.01)*

Pair-wise tests on calculated means were carried out with Student T-test to check the significance of differences in environmental impacts between pairs of cropping systems. After we get the result in EX-ACT calculation, the IR 2 is the most impact to the GHG emission along to all rice typologies. P-value for represented the statistical analyze to show the most significant of rice cultivation where is different or similar trade from IR 2. As on table 29, the indicators between DR 1 and IR 2 are significant different per hectare cultivated but per kg rice produced, there are not different with low significant difference. Thus, DR 1 also has the same impact to climate change as the IR 2 only depending on the country context.

CHAPTER IV: CONCLUSIONS AND RECOMMENDATIONS

IV. Conclusions and Recommendations

IV.1. Conclusions

This report has implemented a joint approach of rice typologies performances and environmental impacts in a diversity of actual rice cropping system in South-East Asia. In all situations, the major impact is due to CH_4 emissions while N_2O emissions are in the range of 6 to 8 % of the total in tCO_2-eq. The classification of rice typology (upland, rainfed low land, deep-water and irrigated rice) is adequate to represent the management systems with an environmental point of view. Those systems have contrasted impacts in terms of GHG emissions, upland rice cultivation can even have positive impact (net C sequestration, but strongly depend of the burning of the residues and the quantity of residues burnt), but in other systems the major categories (rainfed, deep-water and irrigated rice) strongly impact the level of emission.

It is interesting to note that the burning of the residues in irrigated area is not the worst management system of the other straw residues. The organic matter of straw incorporated into the soil, that will be flooded during the next cultivation period, will be also mineralized into methane. But we could expect a rebound negative effect: the community of decomposer will also mineralize other soil organic matter, SOM present (similar to a priming effect).

Water management such as irrigation and drainage is key issue in controlling the amount GHG emitted. Deeping of the level of drainage, the impact on the GHG emissions can be changed by a factor up to 4 to 5. The non-controlled drainage systems (IR 2) present the highest emissions, while intermittently flooded system by drainage (IR 3 to IR 5, without flooded preseason) can present emissions of the same level of the rainfed systems. IR6, with a flooded preseason, presents an intermediary situation.

The tier approach (default coefficient for Tier-1, and regional of national coefficient for Tier-2) has a high effect GHG budgets for all rice systems, except rainfed systems. In Irrigated systems, the Tier-2 approach results in a doubling of total emissions. Deep-water rice systems present strong difference depending on the country, which would require further investigations. The selection of site-specific impact models can help reduce the limitations of the impact assessment's accuracy.

When emission are scaled by potential average yield of each category (4-5 t/ha for deep-water rice, 5-7 t/ha for rainfed lowland rice, 12-13 t/ha for irrigated rice), intermittently flooded system by drainage (IR 3 to IR 5) perform as well as Rainfed systems (RR1 and RR2). IR2 remains the worst systems in terms of climate impact. Deep-water rice shows an intermediary situation strongly depending of the country context.

EX-ACT and LCA approaches gave same levels of GHG emissions, while it was expected it serves as a cross-validation of the 2 approaches. The slights differences are explained mostly by the default values used in each approach. LCA approach confirms that the most important environmental impact is due to GHG emissions far from other impacts to water and soil. The two approaches were developed to address different issues: GHG at landscape approach for EX-ACT, and product oriented for LCA and not focusing only on GHG impact.

IV.2. Recommendations

Our study found that the major policy and conceptual shift toward to the GHG emission are not only relay on the different typology of rice cultivation but also on water management and drainage system. For instance, to reduce the environmental impact of rice cropping categories, the farmer should practice on green manure of organic amendment before and during growing season.

It was also shown that the typology of the rice systems depends on the position in the landscape. Thus, any change or recommendation in terms of policy will have to take into account the possibility or not to change from one systems to another: not all changes will be possible, for instance it is not possible to easily shift from upland rice to any irrigated other systems. But in the irrigated situations, those changes can more easily be promoted, mostly by implementation of improved drainage systems.

There would be interested for policy makers, NGOs, technicians and consultants could carry out EX-ACT for more precise to work with those assessments of GHG emission with rice cropping systems. However, the exclusive use of generic baseline emissions and factors (tier-1 data, such as the ones provided by IPCC) may lead to massive errors we would like to propose the tier-2 information (regional data) it also attempted to more accurately model emissions to water.

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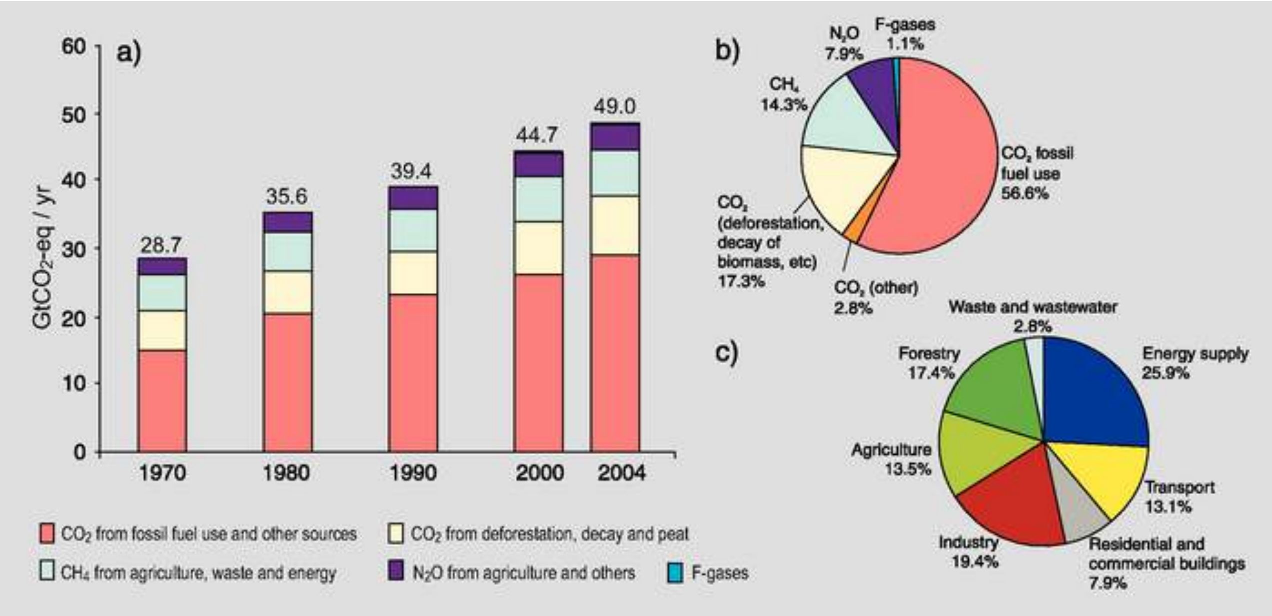
ANNEXES

Annex 1: Global anthropogenic GHG emissions



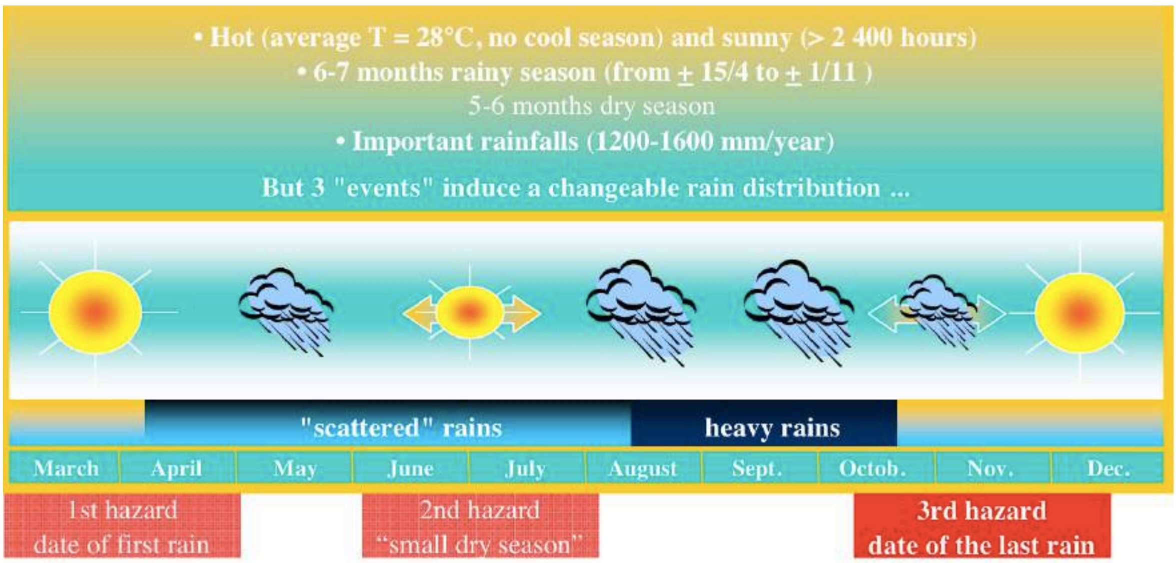
(a) Global annual emissions of anthropogenic GHGs from 1970 to 2004

Includes only carbon dioxide (CO2), methane (CH4), nitrous oxide (N2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphurhexafluoride (SF6), whose emissions are covered by the UNFCCC. These GHGs are weighted by their 100-year Global Warming Potentials (GWPs), using values consistent with reporting under the UNFCCC.

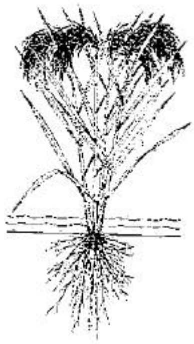
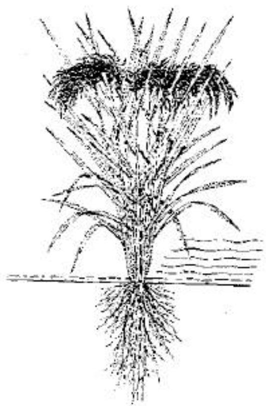
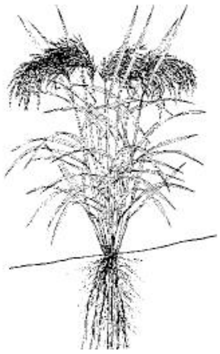
(b) Share of different anthropogenic GHGs in total emissions in 2004 in terms of CO2-eq

(c) Share of different sectors in total anthropogenic GHG emissions in 2004 in terms of CO2-eq. (Forestry includes deforestation.)

Annex 2: Climatic of centre plain of rice cultivation



Annex 3: Characteristics and morphologies of rice plants sought by ecosystem type

Rice's ecosystem	Detail
Irrigated rice direct seeding 	• 3 – 4 panicles per plant • All tillers carry a panicle • 200 – 250 grains per panicle • Very resistant to lodging rod • Dark green leaves, erect, thick • Height: 90 cm • Crop cycle duration: 120 – 130 days • Very vigorous root system • Multiple resistance to pests and diseases • Harvest index: 0.6 • Paddy yield potential: 12 – 13 ton per hectare
Flooded rice (Rainfed lowland rice) 	• 6 – 10 panicles per plant • All tillers carry a panicle • 150 – 200 grains per panicle • Very resistant to lodging rod • Dark green leaves, erect or slightly drooping • Height: 130 cm • Crop cycle duration: 120 – 150 days … often photosensitive rice type adequate between water regime (rain + flood) and rice cycle … • Highly developed root system • Multiple resistance to pests and diseases • Tolerant to submergence of the plant • Grain dormancy strong • Paddy yield potential: 5 – 7 ton per hectare
Rice with deep submergence 	• 5 – 7 panicles per plant • 150 – 200 grains per panicle • Dark green leaves, long and erected • Elongated internode at the deep flood • Roots and tillers on upper nodes • Early root development • Sensitive to photoperiod • Multiple resistance to pests and diseases • Grain dormancy strong • Paddy yield potential: 4 – 5 ton per hectare
Upland rice 	• 5 – 8 panicles per plant • 150 – 200 grains per panicle • Very resistant to lodging rod • Dark green leaves, erected on high, drooping at the base • Height: 130 cm • Crop cycle duration: 100 days • Highly developed root system • Thick and deep roots • Multiple resistances to pests and diseases • Paddy yield potential: 3 – 4 ton per hectare

Source: (IRRI 1984)

Annex 4: Default reference (under native vegetation) soil organic C stock (SOC_{REF}) for mineral soils (tonne C ha^{-1} in 0-30 cm depth)

<table>
<tr><th>Climate region</th><th>HAC soils</th><th>LAC soils</th><th>Sandy soils</th><th>Spodic soils</th><th>Volcanic soils</th><th>Wetland soils</th></tr>
<tr><td>Boreal</td><td>68</td><td>NA</td><td>10#</td><td>117</td><td>20#</td><td>146</td></tr>
<tr><td>Cold temperate, dry</td><td>50</td><td>33</td><td>34</td><td>NA</td><td>20#</td><td rowspan="2">87</td></tr>
<tr><td>Cold temperate, moist</td><td>95</td><td>85</td><td>71</td><td>115</td><td>130</td></tr>
<tr><td>Warm temperate, dry</td><td>38</td><td>24</td><td>19</td><td>NA</td><td>70#</td><td rowspan="2">88</td></tr>
<tr><td>Warm temperate, moist</td><td>88</td><td>63</td><td>34</td><td>NA</td><td>80</td></tr>
<tr><td>Tropical, dry</td><td>38</td><td>35</td><td>31</td><td>NA</td><td>50#</td><td rowspan="4">86</td></tr>
<tr><td>Tropical, moist</td><td>65</td><td>47</td><td>39</td><td>NA</td><td>70#</td></tr>
<tr><td>Tropical, wet</td><td>44</td><td>60</td><td>66</td><td>NA</td><td>130#</td></tr>
<tr><td>Tropical montane</td><td>88*</td><td>63*</td><td>34*</td><td>NA</td><td>80*</td></tr>
</table>

*Data are derived from soil databases described by Jobbagy and Jackson (2000) and Bernoux et al. (2002). Mean stocks are shown. A nominal error estimate of ±90% (expressed as 2x standard deviations as percent of the mean) are assumed for soil-climate types. NA denotes 'not applicable' because these soils do not normally occur in some climate zones. # Indicates where no data were available and default values from 1996 IPCC Guidelines were retained. * Data were not available to directly estimate reference C stocks for these soil types in the tropical montane climate so the stocks were based on estimates derived for the warm temperate, moist region, which has similar mean annual temperatures and precipitation.*

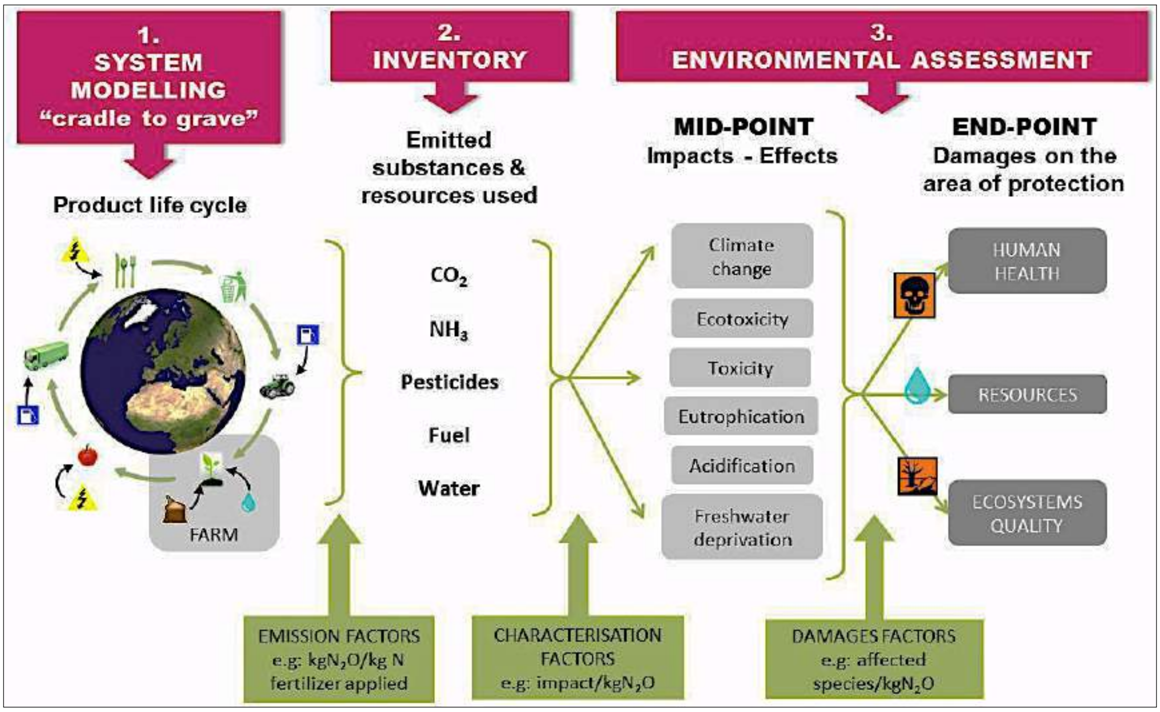
Soils with high activity clay (**HAC**) minerals are lightly to moderately weathered soils, which are dominated by 2:1 silicate clay minerals (in the World Reference Base for Soil Resources (WRB) classification these include Leptosols, Vertisols, Kastanozems, Chernozems, Phaeozems, Luvisols, Alisols, Albeluvisols, Solonetz, Calcisols, Gypsisols, Umbrisols, Cambisols, Regosols; in USDA classification includes Mollisols, Vertisols, high-base status Alfisols, Aridisols, Inceptisols). 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 soils** include 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). **Spondic soils** are the soils exhibiting strong podzolization in WRB classification includes Podzols is in USDA classification Spodosols. **Volcanic soils** are the soils derived from volcanic ash with allophanic mineralogy (in WRB classification Andosols; in USDA classification Andisols). **Wetland soils** are the soils with restricted drainage leading to periodic flooding and anaerobic conditions (in WRB classification Gleysols; in USDA classification Aquic suborders).

Annex 5: Commonly used life cycle impact categories

Impact Category	Scale	Examples of LCI Data (i.e. classification)	Common Possible Environmental impact categories	Description of Characterization Factor
Global Warming	Global	Carbon Dioxide (CO_2) Nitrous Oxide (N_2O) Methane (CH_4) Chlorofluorocarbons (CFCs) Hydro chlorofluorocarbons (HCFCs) Methyl Bromide (CH_3Br)	Global Warming Potential	Converts LCI data to carbon dioxide (CO_2) equivalents Note: global warming potentials can be 50, 100, or 500 year potentials.
Stratospheric Ozone Depletion	Global	Chlorofluorocarbons (CFCs) Hydro chlorofluorocarbons (HCFCs) Halons Methyl Bromide (CH_3Br)	Ozone Depleting Potential	Converts LCI data to trichlorofluoromethane (CFC-11) equivalents.
Acidification	Regional Local	Sulfur Oxides (SOx) Nitrogen Oxides (NOx) Hydrochloric Acid (HCL) Hydroflouric Acid (HF) Ammonia (NH_4)	Acidification Potential	Converts LCI data to hydrogen ($H+$) ion equivalents.
Eutrophication	Local	Phosphate (PO_4) Nitrogen Oxide (NO) Nitrous Oxide (N_2O) Nitrates (NO_3) Nitrates Ammonia (NH_4)	Eutrophication Potential	Converts LCI data to phosphate (PO_4) equivalents.
Freshwater aquatic ecotoxicity	Global	Emission of toxic substance to air, water and/or soil	Freshwater aquatic ecotoxicity potential (FAETP)	Converts LCI data to kg (1,4-dicholorobenzenz equivalents)
Resource Depletion	Global Regional Local	Quantity of minerals used Quantity of fossil fuels used	Resource Depletion Potential	Converts LCI data to a ratio of quantity of resource used versus quantity of resource left in reserve.
Land Use	Global Regional Local	Quantity disposed of in a landfill or other land modifications	Land Availability	Converts mass of solid waste into volume using an estimated density.
Water Use	Regional Local	Water used or consumed	Water Deprivation Potential (Pfister et al., 2009)	Multiply water use by WSI

Reference: EPA's 2006 Document by Mary Ann Curran

Annex 6: Life Cycle Assessment (LCA) @ISO standards 14040&14044



Annex 7: Soil carbon stock in DMC: on left, 3 years of DMC, center Conventional tillage-based management, right undisturbed soil under forest (behind)

Annex 8: Framework of tier structure for AFOLU methods

Tier 1 methods are designed to be the simplest to use, for which equations and default parameter values (e.g., emission and stock change factors) are provided in this volume. Country-specific activity data are needed, but for Tier 1 there are often globally available sources of activity data estimates (e.g., deforestation rates, agricultural production statistics, global land cover maps, fertilizer use, livestock population data, etc.), although these data are usually spatially coarse.

Tier 2 can use the same methodological approach as Tier 1 but applies emission and stock change factors that are based on country- or region-specific data, for the most important land-use or livestock categories. Country-defined emission factors are more appropriate for the climatic regions, land-use systems and livestock categories in that country. Higher temporal and spatial resolution and more disaggregated activity data are typically used in Tier 2 to correspond with country-defined coefficients for specific regions and specialized land-use or livestock categories.

At **Tier 3**, higher order methods are used, including models and inventory measurement systems tailored to address national circumstances, repeated over time, and driven by high-resolution activity data and disaggregated at sub-national level. These higher order methods provide estimates of greater certainty than lower tiers. Such systems may include comprehensive field sampling repeated at regular time intervals and/or GIS-based systems of age, class/production data, soils data, and land-use and management activity data, integrating several types of monitoring. Pieces of land where a land-use change occurs can usually be tracked over time, at least statistically. In most cases these systems have a climate dependency, and thus provide source estimates with interannual variability. Detailed disaggregation of livestock population according to animal type, age, body weight etc., can be used. Models should undergo quality checks, audits, and validations and be thoroughly documented.

Annex 9: Nitrates (NO_3^-) from rice cultivation to water

While nitrogen is the core of fertilization in paddy rice cropping, the crop consumes significantly more ammonium forms than nitrates, conversely to other global crops. Also, owing to flooded conditions, fertilization is rather ammonium and urea-oriented since soluble nitrates may easily leach. As said earlier, according to FAO stats (2002) and in agreement with field data collected in the study areas in 2010-2011, urea and ammonium- based fertilizers from about 85% of all nitrogen fertilizers applied to paddy fields in North and North East Thailand. Therefore, direct nitrates emissions result mostly from complex biochemical transformations (e.g. denitrification) and the whole nitrogen cycle and balance, rather than direct fertilizer loss.

The principles underlying nitrate emission assessment is that (1) nitrates form the remaining components of the overall nitrogen mass balance, which other components have been determined in earlier sections, (2) a large portion (majority) of these nitrates may leach to water compartment, through surface drainage and deep percolation, and (3) such portion refers to the ratio between water that is not used by the crop and overall water supply; in other terms, it relates to water use efficiency.

Accordingly, nitrates potentially leaching from a paddy field are modeled according to a dual N and water mass balance approach suggested by Pathak et al., 2004. N inputs include fertilizer, precipitation, irrigation water and soils (N stock, immobilization). N outputs include losses in surface runoff, groundwater, harvested and exported crop components (rice ears mostly), soil losses (erosion), mineralization, volatilization and denitrification processes.

Annex 10: Nitrogen mass balance

The nitrogen mass balance can be expressed as:

$$\boldsymbol{N_{in} - N_{out} = N_{diff\ soil}} \qquad \text{(Equation 10)}$$

The components of N_{in} (inputs) and N_{out} (outputs) are shown in Table below. $N_{diff\ soil}$ is the difference in N stored in pre-cultivation soil and N stored in post-cultivation soil. Under same cropping systems for years, these soils have long-term stable nitrogen contents; therefore $N_{diff\ soil}$ is deemed negligible. Similarly, organic matter dynamic is deemed balanced overtime, with equal mineralization and immobilization. Other component such as biological nitrogen fixation (-), groundwater contribution (+), and exports by weeds (-) are ignored Pathak et al., 2004.

Components of nitrogen balance in paddy fields

N input (kg N ha^{-1})	N output (kg N ha^{-1})
+ N fertilizer + N from precipitation + N from irrigation water + N from mineralization of organic matter	- N net export by crops - N loss due to emissions of N_2O, NO and NH_3 - N loss due to N_2 emissions - N loss in deep percolation - N loss in drained water - N loss by immobilization in organic matter
$\boldsymbol{\sum}$ **input**	$\boldsymbol{\sum}$ **output**
$\boldsymbol{N_{balance} = 0 = \sum N_{input} - \sum N_{output} - \sum N_{diff\ soil}}$	

All components of in this Table are known, assumed or neglected, except for N losses in deep percolation and surface drainage. These are highly water-soluble nitrates, which may be leaching to the water compartment.

N inputs from fertilizer are to be calculated from fertilizers' formulas and application doses. N inputs from rainfall and irrigation water are to be calculated from data on N contents, average precipitation and irrigation data over the period under consideration (cropping cycle). They may be neglected in the absence of data on N content in rainfall or irrigation.

N uptake by rice plants (mostly ears) are to be calculated from the average mass of exported parts (grain and ears) and their average N contents. If rice straw is also exported off the field, grazed or burned, its N content should also be considered lost. N loss due to emissions of N_2O, NO and NH_3 can be calculated according to section II.2.2, II.2.3 and II.2.4.

N_2 is emitted during the last phases of denitrification. Although not a pollutant, N_2 needs are assessed in order to complete the whole mass balance. Brentrup et al., 2000 proposes an emission factor linked to overall N fertilization:

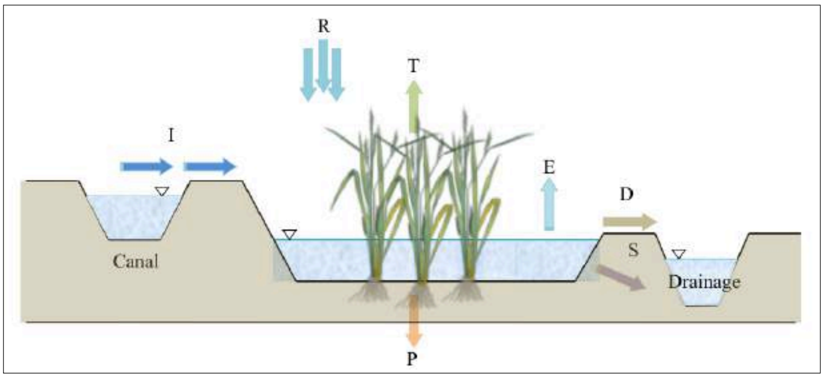
$$N_2 - N\ (kg/ha) = (0.09 \times Total\ N\ units\ per\ ha) \quad \text{(Equation 11)}$$

It is assumed that the remaining components are most nitrates (Nt), which result from nitrification of ammonia. If not absorbed by the crop through evapotranspiration flux, they will potentially be emitted to the water compartment as pollutants, via deep percolation and drainage (Nl). As indicated in table above, they form losses through surface drainage and deep percolation.

Annex 11: Water balance

A water mass balance is needed to ascertain the water use efficiency ratio Ei. It is assumed that the proportion of nitrates bound to drain or leach to the surface and ground water compartments (Leachable nitrates; Nl) during the crop cycle equals the proportion of water that is unused by crops in the paddy system: $(1 - Ei)$.

$$Nl = Nt \times (1 - Ei) \quad \text{(Equation 12)}$$



Concept of paddy field water measuring apparatus, *Source:* (MOWRAM, 2005)

The water balance equation may be expressed as in Figure X, in order to determine percolation and drainage components:

$$DPR + R = I + P - ET \quad \text{(Equation 13)}$$

Where:

DPR	:	Deep-water percolation in mm
R	:	Runoff from the paddy field, which can be expressed as the surface drainage, in mm
I	:	Irrigation water applied during the day in mm
P	:	Precipitation in mm
ET	:	Evapotranspiration in mm

Note: Runoff itself is considered nil, since in common conditions, paddy fields are flat and managed in a way that prevents water from spilling over bunds; farmers maintain water depth between defined minimal and maximal ponding conditions (0 to 150 mm generally). However, at times, and especially at the end of the cropping season, near harvesting, farmers drain the fields off.

Typically, irrigation efficiency, or water use efficiency ratio is:

$$\boldsymbol{Ei} = \frac{\boldsymbol{ET}}{(\boldsymbol{P}+\boldsymbol{I})} \qquad \text{(Equation 14)}$$

It may also be expressed as a function of DPR and R, as follows:

$$\boldsymbol{1} - \boldsymbol{Ei} = \frac{(\boldsymbol{DRP}+\boldsymbol{R})}{(\boldsymbol{P}+\boldsymbol{I})} \qquad \text{(Equation 15)}$$

Either ways, one requires running a water balance model in order to calculate the proportion of nitrates bound to drain or leach to the surface and ground water compartments (Nl). Equation 15 conveniently requires less components to be determined. Average monthly rainfall data, and ET data provided by meteorological services may be used, as well as typical irrigation data collected in the study area. However, more detailed analysis with a dedicated model such as CropWat (Smith, 1992) provides more accurate results.

Annex 12: Phosphorus (P) from rice cultivation to water

Phosphorus (P) is an input to the rice cropping system through chemical fertilizer application, rainwater and irrigation water. Outputs and losses occur through plant uptake and export, percolation and surface drainage which result in pollution (eutrophication). A phosphorus mass balance can be expressed as:

$$\boldsymbol{P_{in}} - \boldsymbol{P_{out}} = \boldsymbol{P_{diff\,soil}} \qquad \text{(Equation 16)}$$

The components of Pin (inputs) and Pout (outputs) are shown in Table below. P_{diff} soil is the difference in P stored in pre-cultivation soil and P stored in the post-cultivation soil. Under same cropping systems for years, paddy soils have long-term stable phosphorus contents; therefore P_{diff} soil is deemed negligible. Similarly, organic matter dynamic is deemed balanced overtime, with equal mineralization and immobilization. Paddy fields being flat and protected by bunds, water hardly ever spills over (except in case of exceptional flooding conditions). So, soil erosion by excessive runoff hardly exists and may be neglected as a possible source of P loss.

Components of phosphorus balance in paddy fields

P input (kg N ha-1)	P output (kg N ha-1)
+ P fertilizer + P from precipitation + P from irrigation water + P from immobilization (= Mineralization of organic matter)	- P uptake by plants - P loss in deep percolation - P loss in drained water - P loss to mineralization of organic matter (= Immobilization)
∑ input	**∑ output**
P balance = 0 = ∑ input - ∑ output – P_{diff} soil	

P inputs from fertilizer are to be calculated from fertilizers' formulas and application doses. P inputs from rainfall and irrigation water are to be calculated from data on P contents, average precipitation and irrigation data over the period under consideration (cropping cycle). They may be neglected in the absence of data on P content in rainfall or irrigation. P uptake by rice plants (mostly ears) are to be calculated from the average mass of exported parts (grain and ears) and their average P contents. If rice straw is also exported off the field or grazed, its P content should also be considered lost. If burning occurs in the field, P is supposed to stay there.

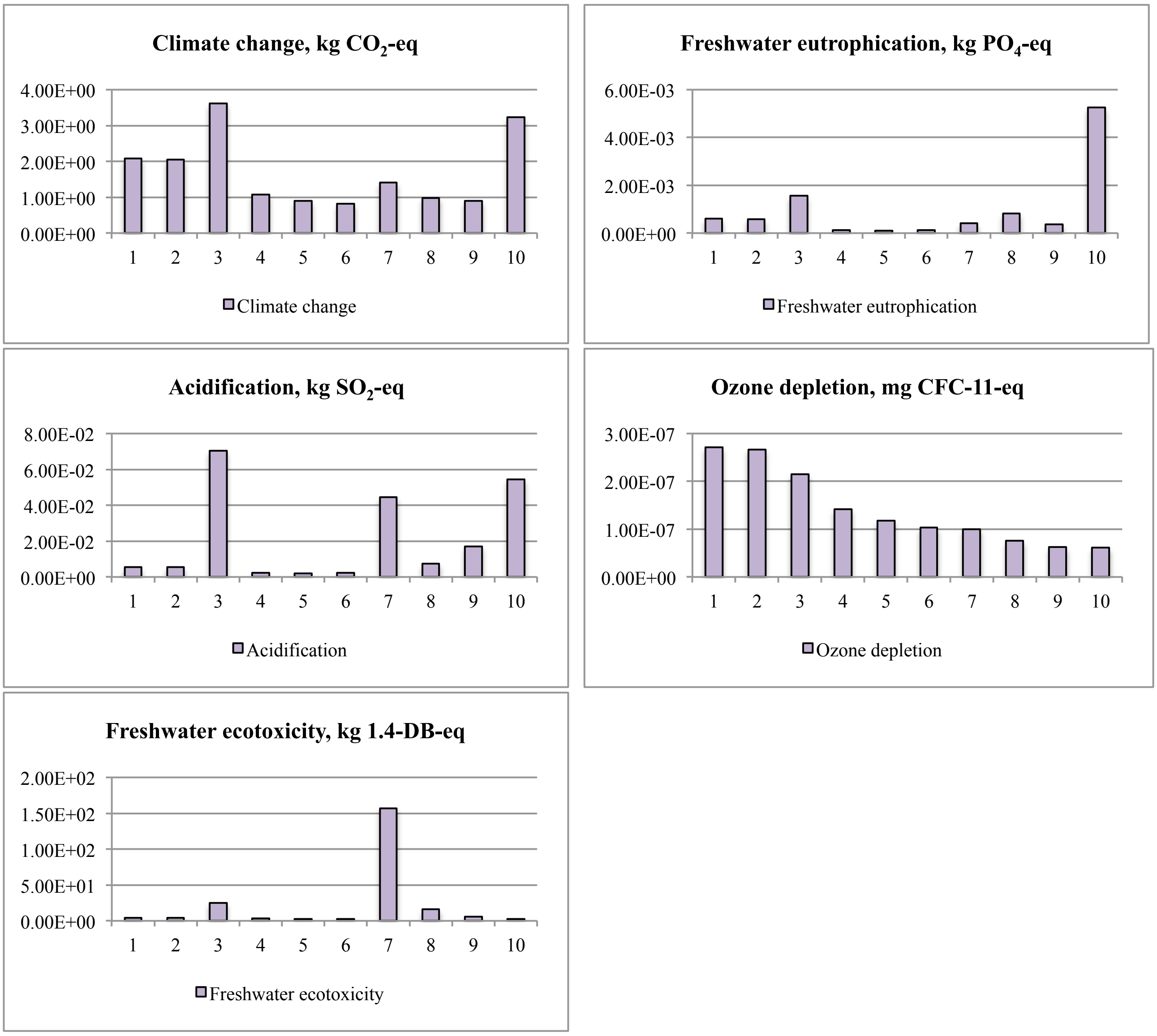
A water mass balance is needed to calculate the total phosphorus losses due to drainage and leaching to surface and groundwater compartments respectively (Pl). It is assumed that the proportion of phosphorus (phosphates) bound to drain or leach to the surface and ground water compartments (Leachable phosphorus; Pl) during the crop cycle equals the proportion of water that is unused by crops in the paddy system: $(1 - Ei)$.

$$\boldsymbol{Pl = Pt * (1 - Ei)} \qquad \text{(Equation 17)}$$

Annex 13: Pesticides from rice cultivation to water and soil

It is assumed that 100% of pesticides ultimately end up in both soil and water compartments, since none is supposed to concentrate in rice grain and leave the field at harvest. Most cropping systems indeed leave straw and rooting systems in the field to decay. In the production areas, most pesticides used are actually insecticides, which are hand-sprayed over the crop at different stages while the field is flooded most of the time. Under the circumstances, it is arbitrarily decided to split emissions equally between soil and water compartments (50%-50%).

Annex 14: Comparison with climate indicators of AgriBalyse database: Crops and Vegetables



Nº	Type of vegetation in AgriBalyse Database
1	Tomate pour la consommation en frais, conventionnelle, sous abri – Moyenne nationale (France)
2	Tomate pour la consommation en frais, sous abri – Moyenne nationale (France)
3	Cocoa, conventionnel, Cabruca
4	Rose fleur coupée hors sol, lutte conventionnelle, chauffée (et éclairée)
5	Rose fleur coupée hors sol, lutte intégrée, chauffée (et éclairée)
6	Rose fleur coupée hors sol, mix de production (lutte conventionnelle et intégrée) – Moyenne nationale (France)
7	Café du Brésil (Robusta), sans pulpe, Brésil
8	Arbuste en conteneur, Moyenne nationale (France)
9	Colza, conventionnel, 9% humidité – Moyenne nationale (France)
10	Riz Thaï (Riz jasmin), Moyenne nationale (Thaïlande)