# Annex 22b

# Greenhouse Gas Methodology and Mitigation Potential Assessment

GCF Funding Proposal

*Thai Rice:*

*Strengthening Climate-Smart Rice Farming*

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# ESTIMATION OF THE GHG MITIGATION POTENTIAL of the proposed GCF project "Strengthening Climate-Smart Rice Farming" in Thailand

# BACKGROUND

Agriculture is the second-largest greenhouse gas (GHG) emitting sector in Thailand. Within the agriculture sector, rice cultivation is responsible for more than 50% of Thailand's emissions (MoNRE, 2022). Rice is the main crop of Thailand, with a total harvested area of more than 10 million hectares (OAE, 2021). There are two principal rice seasons: the main/wet-season rice season starts in May and ends in October/November and the dry-season rice season extends from November to April (Varinruk, 2017).

In order to achieve GHG emission reductions from the Thai agricultural sector, and specifically from rice cultivation, the Ministry of Agriculture and Cooperatives (MoAC) has been collaborating with Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH to implement the Thai Rice NAMA Support Project (NSP) since 2018.

The NAMA Support Project has promoted sustainable and low-GHG emission rice cultivation by adopting a number of innovative technologies and practices, such as alternate wetting and drying (AWD), site-specific nutrient management (SSNM) and straw and stubble management (SSM), among others, in six provinces in the Central Plains of Thailand. Furthermore, the project also aims to develop mitigation technology services and policy formulation and supporting measures.

The success achieved by the NAMA Support Project in the six targeted provinces can, with GCF project support, be scaled-up by national institutions to other parts of Thailand, specifically 21 target provinces in the Central Plain, the North and the North-East regions.

This report presents an estimation of the GHG mitigation potential in rice cultivation that can be achieved by the GCF Thai Rice Project in the 21 target provinces.

# BASELINE SCENARIO

Secondary data from various sources are used to estimate baseline emissions.

*Rice extent*

The rice area of provinces, categorized by cropping season, irrigation conditions (irrigated or rain-fed) and megafarm / non-megafarm status, was collected from the Office of Agricultural Economics (OAE) and used to estimate the rice area by season for the project area in the 21 targeted provinces. The official administrative boundaries were used to disaggregate by region.

The total targeted land area in the 21 provinces is ~718,000 ha, consisting of ~393,000 ha in megafarms and ~325,000 ha in non-megafarms. Approximately 43% of the targeted land area is irrigated and the remaining 57% is rain-fed. In practice, irrigated land can be used to cultivate rice in both dry and wet seasons (i.e. two crops per year) while most non-irrigated land can only be used in the wet season when available rain water is suitable for rice growth (i.e. one crop per year). Therefore, it is assumed that all targeted land area in the 21 provinces is used for rice growing in the wet season.

The planting area in the dry season is lower, based on the proportion of dry/wet season rice reported in OAE's statistics data (OAE, 2018).

Because multiple rice crops can be, and are, planted through the year, the total annual planting area is, in effect, larger than the physical land area.

The GHG emissions (baseline scenario) and emission reductions (project scenario) calculated for both megafarms and non-megafarms in the following sections are also categorized by cultivation season and by irrigation conditions.

*Length of rice season*

The season length for each farmer varies across agro-ecological regions and even within each region, depending on rice varieties, cropping calendar and the physical characteristics of the region. The approximate average season length for each region was estimated based on the rice cropping calendar reported by the Rice Department (RD) of MoAC (Varinruk, 2017).

*Adoption of water management practices*

a. For **irrigated rice** in the Central Plains, a high adoption rate of water-saving practices, including multiple drainage (alternate wetting and drying or AWD) and single drainage during the middle of rice season, is observed – due primarily to four years of operation of the NAMA Support Project (NSP) in this region. The data used for the GCF Thai Rice Project for the 6 provinces in the Central Plains (except Lop Buri, which was not covered by NSP) is sourced from a farm survey conducted by the Thai-German Climate Programme in 2022.

   For 5 'Central-North' provinces (Uthai Thani, Nakhon Sawan, Kamphaeng Phet, PhiChit, and Phitsanulok) that are geologically similar to the Central Plains, as well as Lop Buri province: based on field observations undertaken by GIZ, IRRI, RD, RID and others during (i) implementation of the NAMA Support Project and other foundation / baseline projects, and (ii) ongoing operations of the agricultural extension system, the Central-North provinces are observed to have been influenced by water management activities undertaken by the NSP. Full AWD is not being applied widely, but a simpler form of water-saving practice, namely single aeration, has been adopted. A rate of 50% single aeration in the dry season and 30% in the wet season is applied in line with field observations (with the seasonal differentiation due to higher rainfall in the wet season). This baseline also ensures conservativeness in the estimation of the project's mitigation potential.

   In the North, Chiang Mai and Chiang Rai have not yet adopted new water management activities at meaningful scale. Farmers in these provinces follow traditional practices and retain as much water in the field as possible. Therefore, the model assumes 100% continuous flooding (CF) in irrigated rice in these provinces.

   For provinces in the North-East, continuous flooding is widely applied, as described in the following study (from 2017 but still relevant): https://www.mdpi.com/2077-0472/7/1/4. The model therefore assumes 75% continuous flooding in irrigated areas in the North-East while the rain-fed areas remain 100% rain-fed.

b. For **rain-fed rice**, it is observed through in-field measurements that significant methane reduction can be achieved through improved irrigation water management during the wet season. However, farm survey data (GIZ, 2022) shows very low current adoption of AWD (8%) and single aeration (7%) in the Central Plains during the wet season, and no adoption in the dry season. These empirical values have been adopted to estimate baseline emissions for the region. For all provinces in the North and North-East regions, CF is assumed to be fully practised (100%) in both dry and wet seasons.

*Nitrogen fertilizer use*

The average rate of nitrogen fertilizer used (96 kgN/ha and 107 kgN/ha in dry and wet seasons, respectively) given by Stuart et al. (2018) is used as the baseline value for the Central Plains. Based on empirical observations, it is estimated that the application rate is 20% lower in the other regions.

*Rice residue management*

The average rates of different rice residue (straw and stubble) management methods (i.e., burning, incorporation and removal) under irrigated and rain-fed rice in different regions reported by Cheewaphongphan et al. (2018) are used in this estimation. However, Cheewaphongphan et al. (2018) do not differentiate between dry and wet seasons. It is assumed that burning and removal rates during the wet season are half the levels reported by Cheewaphongphan et al. (2018) and that incorporation rates are correspondingly higher. Generally, the estimated rates of straw burning in this study are low.
It should be noted that changes of straw burning do not significantly affect GHG emissions. Therefore, we do not change the rates of burning in the scenarios for the calculation of GHG emissions in order to avoid introducing an unnecessary factor of uncertainty and confusion. It may be warranted to assess more current rates of straw burning and to introduce approaches to reduce the rates with the aim of 'zero burning'. However, this is not being considered in this GHG assessment.

*Methane emission factor*

A number of studies identify methane emission factors (EFs) for rice in different areas and farming contexts, with a wide range of numerical estimates cited. No consolidation of these EFs has yet been undertaken and no disaggregated EF has officially been published. Therefore, standard $CH_4$ EFs provided by the IPCC (IPCC, 2019) for South-East Asia are used in ex ante project calculations. (EFs can and will be refined during project implementation, as empirical data becomes available).

*Nitrous oxide emission factor*

Similar to the methane emission factors, standard nitrous oxide (N2O) emission factors (based on fertilizer input) as described by IPCC (IPCC, 2019) have been used in this study. These emission factors vary with water management. The N2O emission factors used in this study are lower in continuously flooded rice and higher in single and multiple aeration scenarios such as AWD. This approach was taken in order to ensure we account for possible increases of nitrous oxide when shifting to non-continuously flooded rice and to remain conservative in estimating the overall GHG reduction potential.

# PROJECT (MITIGATION) SCENARIO

## Prioritized interventions by region

The mitigation potential estimated for the project area is based on scenarios of adoption of low-emission technologies and practices introduced into each region, considering the biophysical and social characteristics of each region.

The climate-smart agriculture technologies and practices (CSA T&Ps) addressed by the Thai Rice Project are:

- Laser land levelling (LLL)
- Alternate wetting and drying (AWD)
- Site-specific nutrient management (SSNM)
- Straw and stubble management (SSM)
- Integrated Pest Management (IPM)
- Rice variety diversification
- Crop diversification, rotation
- Dry direct-seeded rice (DSR)
- Farm-level water management (FWM)
- Agro-met advisory services

Among these CSA T&Ps, only the key interventions in each region are considered in the greenhouse gas (GHG) calculations.

Furthermore, <u>the impact of LLL is not included in the GHG calculations</u>. LLL certainly plays a crucial role in supporting and enhancing water-saving technologies. Poorly levelled fields are a major constraint for farmers to effectively manage irrigation water in rice fields. Different on-station and on-farm trials showed that LLL increases cropping system productivity, water-use efficiency as well as profitability (Jat et al., 2009; Aryal et al., 2025). It was further sown that LLL is “scale-neutral”, meaning it is not biased towards large fields (Aryal et al., 2015). A cost/benefit analysis of LLL in Thailand showed a break-even point for farmers after around three seasons due to higher yield and reduced inputs (Nguyen-Van-Hung et al., 2022). An unpublished multi-factorial regression analysis of data from the NSP shows a significant attribution of LLL to the likelihood of adoption of AWD. Measurements on a small number of plots in Thailand show a higher mitigation effect of AWD in laser-levelled fields than in fields subjected to traditional levelling.

However, while LLL undoubtedly exerts a positive impact on water use efficiency – and hence reduces water usage and unnecessary pooling, and hence $CH_4$ emissions, in conjunction with AWD or single aeration – the scientific literature is simply too scant to derive meaningful LLL emission factors. A positive and very welcome by-product of the Thai Rice Project will be to generate data that can be used to quantify the mitigation impact of LLL.

Expected CSA adoption rates after 5 years are: <u>80% of megafarms</u> and <u>60% of non-megafarms</u> in each region – which is equivalent to <u>72% of all farms</u>. These adoption rates are based on the empirical experiences of the NSP and other donor-funded rice projects in Thailand.

<u>Central Plains</u>

*Water management:* Applying water-saving practices (single aeration schemes and AWD) is feasible under the biophysical conditions of the Central Plains, as the practices already have high adoption rates in both dry and wet seasons (largely due to support from the NSP). With the support of the GCF Thai Rice Project, farmers will shift the current area of single aeration and CF to AWD.

The 5 provinces in the Central Plains region that have not participated in the NAMA Support Project – namely, Uthai Thani, Nakhon Sawan, Kamphaeng Phet, PhiChit and Phitsanulok – have similar agro-environmental conditions as the NSP Central Plains provinces. As an outcome of the Thai Rice Project, these provinces are foreseen to achieve at least the current (baseline) adoption rate of the NSP Central Plains provinces.

*SSNM*: It is feasible to mitigate direct and indirect $N_2O$ emissions by reducing 10% of N input in both dry and wet seasons.

*SSM*: In 2015-2016, burning of rice residues was a common practice in the Central Plains. More than one-third of rice residue is burnt at the end of the dry season (Cheewaphongphan et al., 2018). For the project (mitigation) scenario, it is assumed – conservatively – that one-quarter of the baseline straw burning will be avoided. This amount will be removed from the field for other purposes. There will be no reduction of straw burning in the wet season due to wet condition at the end of the season.

Incorporating rice residues into the soil can generate high $CH_4$ emissions under flooded conditions. In order to reduce $CH_4$ emissions while avoiding the risk of soil fertility reductions, the incorporation of stubble will only be promoted in the wet season. With the use of combine harvesters, the average height of stubble is 30 cm, which is roughly equivalent to 2.4 tonne/ha or 48% of the total weight of rice residue.

The GIZ field survey (2022) shows that over 80% of residues are incorporated shortly before the start of the following season in the NSP provinces. While this survey was conducted in the Central Plains, it is assumed that the same baseline applies in the other regions. The Thai Rice Project will promote early incorporation and will target a high level of early incorporation: 50% of residues will be incorporated more than one month before the following season. This shift will bring additional mitigation benefit because straw can decompose in non-flooded conditions when being incorporated early.

<u>North</u>

*Water management*: The two Northern provinces, Chiang Mai and Chiang Rai, will start to adopt innovative water management practices by shifting 30% of their irrigated rice areas from CF to single aeration as a conservative estimate..

*SSNM*: Except in Chiang Mai and Chiang Rai in the North, where the nitrogen application rate for rice is rather low (77kg N/ha in the dry season and 85 kg N/ha in the wet season), farmers in central provinces will reduce 10% of nitrogen input in both dry and wet seasons.

*SSM*: Adoption of SSM in the North region will be comparable to that in the Central Plains.

<u>North-East</u>

*Water management*: 25% of rice land will move from current single aeration to multiple aerations (or AWD), while 25% of CF farms will practise at least one aeration during the rice season. The GHG modelling assumes that these moderate uptake rates can be reached without a strong emphasis on LLL, but introduction of the technology – especially in the megafarm context – will, where it occurs, be beneficial.

*SSNM*: Due to the low nitrogen rate that is currently applied, no N reduction is recommended for farms in the North-East. SSNM introduction in the region will only focus on N use efficiency (splitting N fertilizer into small doses and introducing the rotation of rice and nitrogen-fixing crops). This will have negligible effects on GHG emissions and there are no established ways of estimating the mitigation impact.

*SSM*: Adoption of SSM in the North-East region will be similar as in the Central Plains.

Other climate-smart interventions

*IPM*: Reducing herbicide and pesticide use from a high/intensive level to a recommended level will mitigate 190.7 kg $CO_2$e/ha/season (Nguyen, 2019).

*Short-duration rice varieties*: The emission rate (kg $CO_2$e/ha/day) depends on the set of applied interventions, the rice season and water conditions (irrigated and rain-fed). Reducing 1 day of crop duration will reduce approximately 0.7–0.8% of the total GHG emissions associated with a typical growth duration in Thailand of 125-150 days. Depending on the growing conditions, this could result in a reduction of 2.97-9.78 kg $CO_2$e/ha.

*DSR*: Non-flooding conditions before the rice season contribute to a mitigation potential of 331 kg $CO_2$e/ha/season (Janz et al., 2019). In addition, multiple drainage water management can be expected with dry DSR. Thus, in some Thai Rice Project areas multiple aerations will be achieved through AWD while in others through dry DSR.

The three above-mentioned climate-smart interventions are not included in the assessment of the GHG reduction potential of the GCF Thai Rice Project because baseline information, such as level of IPM adoption by region, suitable and feasible short-duration rice varieties for different regions or suitable areas for DSR, is lacking. Hence, the mitigation benefits from these interventions should be seen as additional climate benefits not accounted for in the GHG assessment. During project implementation, the project team will collect relevant data to quantify these climate benefits.

# CALCULATION TOOL

The GHG mitigation estimate is calculated using the “Source-selective and emission-adjusted GHG calculator for cropland” or SECTOR (Wassmaan et al., 2018). The conversion and scaling factors given by the 2019 refinement of the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC, 2019) are used.

# RESULTS

*Targeted planting area*

Tables 1 and 2 present the planting rice areas of megafarms and non-megafarms categorized by cultivation season and by irrigation conditions in each of the targeted provinces.

The total planting area of the targeted farms is ~1.1 million ha, of which the wet season area is twice that of the dry season (~718,000 ha and ~354,000 ha respectively). Megafarms account for slightly over half of the total area with ~541,200 ha (~393,000 ha and ~148,200 ha in the wet and dry seasons, respectively) (Table 1); and the remaining 49.5% (~531,300 ha) belongs to non-megafarms (~325,100 and ~206,200 ha in the wet and dry seasons, respectively) (Table 2).

In terms of irrigation conditions, 54% of the planting area is irrigated (~577,900 ha) and 46% (~494,600 ha) is rain-fed. Nearly two-thirds of the megafarm area is rain-fed (~342,700 ha) while over 70% of the non-megafarm area is irrigated (~379,400 ha).

*Baseline emissions*

Table 3 presents detailed estimates of GHG emissions from megafarms and non-megafarms by province, and Table 4 aggregates GHG emissions by farm-type, season and irrigation conditions.

Total GHG emissions under the baseline scenario are 6.18 $MtCO_2e$/year, 49% of which are from megafarms and 51% from non-megafarms. This makes an average emission intensity of 5.76 $tCO_2e$/ha.

Since the planting area in the wet season is twice that in the dry season, the wet season is responsible for the majority of GHG emissions: 74% of GHG emissions from megafarms and 69% of GHG emissions from non-megafarms occur during the wet season.

Less than 40% of baseline GHG emissions are from rain-fed areas (2.4 $MtCO_2e$/year), while over 60% come from irrigated areas (3.8 $MtCO_2e$/year).

Of the total GHG emissions from megafarms (3 $MtCO_2e$/year), irrigated areas account for 45% and rain-fed areas for 55%. Non-megafarms emit 3.2 $MtCO_2e$/year, of which 76% come from irrigated areas and 24% from rain-fed areas.

*Emissions with adopted interventions*

If 100% of the targeted planting area in both dry and wet seasons in the 21 project provinces were to adopt CSA technologies and practices, annual GHG emissions would be reduced from 6.18 $MtCO_2e$/year (baseline emissions) to 4.7 $MtCO_2e$/year (Table 5).

More than 70% of this GHG abatement would be produced in the wet season (3.3 $MtCO_2e$/year) and nearly 30% (1.4 $MtCO_2e$/year) would be produced in the dry season. There would be no significant difference between the amount of GHG emissions from megafarms and of non-megafarms.

However, as noted above, the GHG modelling adopts a more conservative approach. Based on the empirical experiences of the NSP and other donor-funded rice projects in Thailand, it is assumed that megafarm members (who generally have better infrastructure and farming management) will adopt interventions on 80% of their planting area by the 5$^{th}$ (final) year of the project. Non-megafarm farmers generally have lower adoption capacities and are assumed to adopt interventions on 60% of their planting area by project-end (despite having full access to introduced climate-smart technologies).

Tables 6 and 7 present GHG emissions with an adoption rate of 80% for megafarms and 60% for non-megafarms, respectively. Under this assumption, the total GHG emissions will be 5.16 $MtCO_2e$/year, consisting of 2.50 $MtCO_2e$/year from megafarms (Table 6) and 2.66 $MtCO_2e$/year from non-megafarms (Table 7). The proportions of GHG emissions from irrigated and rain-fed areas in megafarms show a slight difference (41% and 59%, respectively), while those of non-megafarms are considerably different (74% and 26%, respectively).

Table 8 shows aggregations of GHG emissions by megafarms and non-megafarms, season and irrigation regime. The estimation obviously indicates that GHG emissions in the wet season are higher (2.4 times higher) than those in the dry season.

*Mitigation potential*

If the climate-smart interventions were to be fully and immediately adopted by 100% of targeted farms, the project would reduce a total of 7.42 Mt$CO_2$e over 5 years, or 1.48 Mt$CO_2$e annually.

However, with the capped adoption rates used in the GHG modelling (i.e. adoption capped at 80% of the megafarm area and 60% of the non-megafarm area), annual mitigation in the 5$^{th}$ year will be 1.01 Mt$CO_2$e/year, consisting of 50% from megafarms and 50% from non-megafarms (Table 9).

As shown in Table 9, the majority of reductions will take place in the wet season (769.14 kt$CO_2$e), approximately three times more than the reductions in the dry season (248.64 kt$CO_2$e). Considerably more GHG emissions will be reduced on irrigated land than on rain-fed land (735,35 kt$CO_2$e and 282.43 kt$CO_2$e, respectively).

In reality, the mitigation potential of 1.02 Mt$CO_2$e/year is likely not achievable immediately – i.e. in the first year of the project.

If, instead, a more realistic, step-wise adoption schedule is applied – 10% in Year 1, 20% in Year 2, 40% in Year 3, 70% in Year 4 and 100% in Year 5[1] – the project will reduce a total of 2.44 Mt$CO_2$e along its mitigation pathway over 5 years (Figure 1).

Assuming that the project continues to have an impact over 15 years (the project influence period or lifespan), the project's total mitigation potential will be 12.56 Mt$CO_2$e.

[1] Where 100% in Year 5 represents the capped adoption rate being achieved: i.e. 80% of megafarms and 60% of non-megafarms, or 72% of all farms. Expressed differently, the adoption rate can be stated as 7.2% in Year 1 (calculated as 10% of the 72% climate-smart agriculture adoption cap); 14.4% in Year 2 (20% of the adoption cap); 28.8% in Year 3 (40% of the adoption cap); 50.4% in Year 4 (70% of the adoption cap); and 72% in Year 5 (when the project reaches the adoption cap).

**Table 1. Estimated planting area of megafarms by province, season, and irrigation conditions**

(IR = Irrigated; RF = Rain-Fed)

| Province | Region | Planting area (1,000 ha) | | | |
|---|---|---|---|---|---|
| | | Dry season | | Wet season | |
| | | IR | RF | IR | RF |
| Chiang Mai | North | 1.29 | 0.20 | 3.35 | 1.03 |
| Chiang Rai | North | 1.44 | 2.71 | 4.05 | 8.10 |
| Uthai Thani | Central Plains | 2.05 | 1.31 | 1.97 | 4.53 |
| Nakhon Sawan | Central Plains | 5.59 | 6.13 | 3.69 | 12.18 |
| Kamphaeng Phet | Central Plains | 4.73 | 1.44 | 2.85 | 4.56 |
| PhiChit | Central Plains | 5.28 | 5.48 | 5.73 | 10.65 |
| Phitsanulok | Central Plains | 8.62 | 4.84 | 4.05 | 7.68 |
| Lop Buri | Central Plains | 5.16 | 0.23 | 5.06 | 2.87 |
| Chainat | Central Plains | 5.43 | 0.38 | 8.04 | 1.07 |
| Ang Thong | Central Plains | 0.71 | - | 0.94 | - |
| Pathum Thani | Central Plains | 5.06 | - | 5.53 | - |
| Sing buri | Central Plains | 2.26 | - | 2.85 | - |
| Ayuthaya | Central Plains | 5.52 | - | 6.01 | - |
| Suphan buri | Central Plains | 9.66 | 0.25 | 8.72 | 2.81 |
| Si sa ket | North-East | 11.44 | 4.76 | 2.17 | 39.75 |
| Kalasin | North-East | 4.98 | 0.21 | 1.71 | 5.06 |
| Ubon Ratchathani | North-East | 9.82 | 1.26 | 1.87 | 21.11 |
| Roi Et | North-East | 1.88 | 5.87 | 2.56 | 28.26 |
| Surin | North-East | 1.38 | 2.74 | 3.24 | 48.57 |
| Nakhon Ratchasima | North-East | 12.86 | 0.86 | 7.70 | 38.94 |
| Buriram | North-East | 2.14 | 2.27 | 9.09 | 64.60 |
| **Total (seasonal)** | | **148.22** | | **392.96** | |
| **Total (annual)** | | **541.18** | | | |

**Table 2. Estimated planting area of non-megafarms by province, season and irrigation conditions**

(IR= Irrigated; RF=Rain-Fed)

| Province | Region | Planting area (1,000 ha) | | | |
|---|---|---|---|---|---|
| | | Dry season | | Wet season | |
| | | IR | RF | IR | RF |
| Chiang Mai | North | 2.01 | 0.31 | 3.41 | 3.41 |
| Chiang Rai | North | 1.11 | 2.10 | 4.69 | 4.69 |
| Uthai Thani | Central Plains | 5.93 | 3.80 | 9.40 | 9.40 |
| Nakhon Sawan | Central Plains | 7.86 | 8.62 | 11.16 | 11.16 |
| Kamphaeng Phet | Central Plains | 11.04 | 3.36 | 8.66 | 8.66 |
| PhiChit | Central Plains | 7.84 | 8.15 | 12.18 | 12.18 |
| Phitsanulok | Central Plains | 13.81 | 7.76 | 9.40 | 9.40 |
| Lop Buri | Central Plains | 10.82 | 0.49 | 8.32 | 8.32 |
| Chainat | Central Plains | 10.44 | 0.73 | 17.51 | - |
| Ang Thong | Central Plains | 10.81 | - | 14.33 | - |
| Pathum Thani | Central Plains | 19.20 | - | 20.97 | - |
| Sing buri | Central Plains | 13.14 | - | 16.60 | - |
| Ayuthaya | Central Plains | 18.25 | - | 19.85 | - |
| Suphan buri | Central Plains | 12.43 | 0.32 | 14.83 | - |
| Si sa ket | North-East | 2.63 | 1.09 | 4.82 | 4.82 |
| Kalasin | North-East | 7.12 | 0.30 | 4.84 | 4.84 |
| Ubon Ratchathani | North-East | 5.67 | 0.73 | 6.64 | 6.64 |
| Roi Et | North-East | 0.72 | 2.26 | 5.94 | 5.94 |
| Surin | North-East | 0.25 | 0.50 | 4.76 | 4.76 |
| Nakhon Ratchasima | North-East | 3.14 | 0.21 | 5.70 | 5.70 |
| Buriram | North-East | 0.61 | 0.65 | 10.58 | 10.58 |
| **Total (seasonal)** | | **206.23** | | **325.08** | |
| **Total (annual)** | | **531.32** | | | |

**Table 3. Baseline GHG emissions of the target provinces by farm-type, season and irrigation condition**

(IR= Irrigated; RF=Rain-Fed)

| Province | Region | GHG emissions ($ktCO_2e$/season) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Megafarm | | | | Non-megafarm | | | |
| | | Dry | | Wet | | Dry | | Wet | |
| | | IR | RF | IR | RF | IR | RF | IR | RF |
| Chiang Mai | North | 7.34 | 0.75 | 32.81 | 5.83 | 11.40 | 1.16 | 33.31 | 19.24 |
| Chiang Rai | North | 8.19 | 10.10 | 39.58 | 45.75 | 6.33 | 7.81 | 45.92 | 26.53 |
| Uthai Thani | Central Plains | 10.38 | 4.95 | 18.20 | 26.35 | 30.03 | 14.33 | 86.79 | 54.72 |
| Nakhon Sawan | Central Plains | 28.29 | 23.14 | 34.06 | 70.88 | 39.80 | 32.56 | 103.04 | 64.97 |
| Kamphaeng Phet | Central Plains | 23.95 | 5.43 | 26.32 | 26.55 | 55.93 | 12.69 | 79.91 | 50.38 |
| PhiChit | Central Plains | 26.71 | 20.70 | 52.88 | 62.00 | 39.72 | 30.77 | 112.41 | 70.88 |
| Phitsanulok | Central Plains | 43.65 | 18.29 | 37.42 | 44.68 | 69.93 | 29.29 | 86.73 | 54.68 |
| Lop Buri | Central Plains | 26.11 | 0.88 | 46.66 | 16.70 | 54.82 | 1.84 | 76.77 | 48.41 |
| Chainat | Central Plains | 23.81 | 1.38 | 45.37 | 5.39 | 45.76 | 2.65 | 98.84 | - |
| Ang Thong | Central Plains | 3.11 | - | 5.31 | - | 47.38 | - | 80.88 | - |
| Pathum Thani | Central Plains | 22.19 | - | 31.20 | - | 84.19 | - | 118.35 | - |
| Sing buri | Central Plains | 9.91 | - | 16.11 | - | 57.63 | - | 93.66 | - |
| Ayuthaya | Central Plains | 24.22 | - | 33.89 | - | 80.03 | - | 112.00 | - |
| Suphan buri | Central Plains | 42.36 | 0.90 | 49.22 | 14.11 | 54.49 | 1.15 | 83.69 | - |
| Si sa ket | North-East | 83.08 | 16.62 | 18.91 | 194.26 | 19.11 | 3.82 | 42.05 | 23.56 |
| Kalasin | North-East | 36.14 | 0.72 | 14.93 | 24.73 | 51.68 | 1.03 | 42.24 | 23.66 |
| Ubon Ratchathani | North-East | 71.31 | 4.41 | 16.32 | 103.15 | 41.19 | 2.55 | 57.91 | 32.44 |
| Roi Et | North-East | 13.62 | 20.50 | 22.36 | 138.12 | 5.25 | 7.90 | 51.83 | 29.03 |
| Surin | North-East | 10.01 | 9.56 | 28.26 | 237.34 | 1.84 | 1.76 | 41.49 | 23.24 |
| Nakhon Ratchasima | North-East | 93.38 | 3.02 | 67.17 | 190.28 | 22.84 | 0.74 | 49.75 | 27.87 |
| Buriram | North-East | 15.53 | 7.92 | 79.27 | 315.70 | 4.46 | 2.27 | 92.27 | 51.69 |
| **Total (seasonal)** | | **772.55** | | **2,238.07** | | **978.13** | | **2,191.15** | |
| **Total (by farm-type per year)** | | **3,010.62** | | | | **3,169.28** | | | |
| **Total (annual)** | | **6,179.91** | | | | | | | |

**Table 4. Aggregation of baseline GHG emissions by farm-type, season and irrigation condition**

(IR = Irrigated; RF = Rain-Fed)

| Farm-type | GHG emissions (kt$CO_2$e/season) | | | |
|---|---|---|---|---|
| | Dry | | Wet | |
| | IR | RF | IR | RF |
| Megafarms | **623.29** | **149.26** | **716.26** | **1,521.81** |
| Non-megafarms | **823.81** | **154.32** | **1,589.85** | **601.30** |
| **Total (by irrigation condition per season)** | 1,447.10 | 303.59 | 2,306.11 | 2,123.11 |
| **Total (seasonal)** | **1,750.68** | | **4,429.22** | |
| **Total (annual)** | **6,179.91** | | | |

**Table 5. GHG emissions from megafarms with 100% adopted interventions by province, season and irrigation condition**

(IR= Irrigated; RF=Rain-Fed)

| Province | Region | GHG emissions ($ktCO_2e$/season) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Megafarm | | | | Non-megafarm | | | |
| | | Dry | | Wet | | Dry | | Wet | |
| | | IR | RF | IR | RF | IR | RF | IR | RF |
| Chiang Mai | North | 6.37 | 0.68 | 23.47 | 4.68 | 9.88 | 1.05 | 23.83 | 15.46 |
| Chiang Rai | North | 7.11 | 9.14 | 28.32 | 36.76 | 5.49 | 7.06 | 32.85 | 21.32 |
| Uthai Thani | Central Plains | 7.56 | 4.44 | 10.44 | 20.96 | 21.89 | 12.85 | 49.79 | 43.54 |
| Nakhon Sawan | Central Plains | 20.62 | 20.75 | 19.54 | 56.39 | 29.01 | 29.19 | 59.11 | 51.69 |
| Kamphaeng Phet | Central Plains | 17.46 | 4.87 | 15.10 | 21.13 | 40.77 | 11.38 | 45.85 | 40.09 |
| PhiChit | Central Plains | 19.47 | 18.56 | 30.34 | 49.33 | 28.95 | 27.60 | 64.49 | 56.39 |
| Phitsanulok | Central Plains | 31.82 | 16.40 | 21.47 | 35.55 | 50.97 | 26.27 | 49.76 | 43.51 |
| Lop Buri | Central Plains | 19.04 | 0.79 | 26.77 | 13.29 | 39.96 | 1.65 | 44.04 | 38.51 |
| Chainat | Central Plains | 18.83 | 1.22 | 32.88 | 4.07 | 36.21 | 2.34 | 71.62 | - |
| Ang Thong | Central Plains | 2.46 | - | 3.84 | - | 37.49 | - | 58.61 | - |
| Pathum Thani | Central Plains | 17.56 | - | 22.61 | - | 66.61 | - | 85.76 | - |
| Sing buri | Central Plains | 7.84 | - | 11.67 | - | 45.60 | - | 67.87 | - |
| Ayuthaya | Central Plains | 19.16 | - | 24.56 | - | 63.32 | - | 81.16 | - |
| Suphan buri | Central Plains | 33.52 | 0.79 | 35.66 | 10.66 | 43.11 | 1.02 | 60.65 | - |
| Si sa ket | North-East | 64.68 | 15.41 | 13.27 | 165.28 | 14.87 | 3.54 | 29.51 | 20.04 |
| Kalasin | North-East | 28.13 | 0.67 | 10.47 | 21.04 | 40.24 | 0.96 | 29.64 | 20.13 |
| Ubon Ratchathani | North-East | 55.51 | 4.09 | 11.45 | 87.76 | 32.07 | 2.36 | 40.63 | 27.60 |
| Roi Et | North-East | 10.60 | 19.01 | 15.69 | 117.51 | 4.09 | 7.33 | 36.37 | 24.70 |
| Surin | North-East | 7.80 | 8.87 | 19.83 | 201.92 | 1.43 | 1.63 | 29.11 | 19.77 |
| Nakhon Ratchasima | North-East | 72.70 | 2.80 | 47.13 | 161.89 | 17.78 | 0.68 | 34.91 | 23.71 |
| Buriram | North-East | 12.09 | 7.34 | 55.62 | 268.59 | 3.47 | 2.11 | 64.74 | 43.98 |
| **Total (seasonal)** | | **616.16** | | **1,756.95** | | **772.24** | | **1,550.74** | |
| **Total (by farm-type per year)** | | **2,373.11** | | | | **2,322.98** | | | |
| **Total (annual)** | | **4,696.09** | | | | | | | |

**Table 6. GHG emissions from megafarms in the 5th year with 80% adopted interventions by province, season and irrigation condition**

(IR=Irrigated; RF=Rain-Fed)

| Province | Region | GHG emissions ($ktCO_2e$/season) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Category 1: 80% adopted | | | | Category 2: 20% non-adopted | | | |
| | | Dry | | Wet | | Dry | | Wet | |
| | | IR | RF | IR | RF | IR | RF | IR | RF |
| Chiang Mai | North | 5.09 | 0.54 | 18.78 | 3.75 | 1.47 | 0.15 | 6.56 | 1.17 |
| Chiang Rai | North | 5.68 | 7.31 | 22.65 | 29.41 | 1.64 | 2.02 | 7.92 | 9.15 |
| Uthai Thani | Central Plains | 6.05 | 3.55 | 8.35 | 16.77 | 2.08 | 0.99 | 3.64 | 5.27 |
| Nakhon Sawan | Central Plains | 16.50 | 16.60 | 15.63 | 45.11 | 5.66 | 4.63 | 6.81 | 14.18 |
| Kamphaeng Phet | Central Plains | 13.96 | 3.90 | 12.08 | 16.90 | 4.79 | 1.09 | 5.26 | 5.31 |
| PhiChit | Central Plains | 15.58 | 14.85 | 24.27 | 39.46 | 5.34 | 4.14 | 10.58 | 12.40 |
| Phitsanulok | Central Plains | 25.45 | 13.12 | 17.17 | 28.44 | 8.73 | 3.66 | 7.48 | 8.94 |
| Lop Buri | Central Plains | 15.23 | 0.63 | 21.42 | 10.63 | 5.22 | 0.18 | 9.33 | 3.34 |
| Chainat | Central Plains | 15.07 | 0.97 | 26.30 | 3.25 | 4.76 | 0.28 | 9.07 | 1.08 |
| Ang Thong | Central Plains | 1.97 | - | 3.08 | - | 0.62 | - | 1.06 | - |
| Pathum Thani | Central Plains | 14.05 | - | 18.09 | - | 4.44 | - | 6.24 | - |
| Sing buri | Central Plains | 6.27 | - | 9.34 | - | 1.98 | - | 3.22 | - |
| Ayuthaya | Central Plains | 15.33 | - | 19.65 | - | 4.84 | - | 6.78 | - |
| Suphan buri | Central Plains | 26.81 | 0.63 | 28.53 | 8.53 | 8.47 | 0.18 | 9.84 | 2.82 |
| Si sa ket | North-East | 51.74 | 12.33 | 10.62 | 132.22 | 16.62 | 3.32 | 3.78 | 38.85 |
| Kalasin | North-East | 22.51 | 0.54 | 8.38 | 16.83 | 7.23 | 0.14 | 2.99 | 4.95 |
| Ubon Ratchathani | North-East | 44.41 | 3.27 | 9.16 | 70.21 | 14.26 | 0.88 | 3.26 | 20.63 |
| Roi Et | North-East | 8.48 | 15.21 | 12.55 | 94.01 | 2.72 | 4.10 | 4.47 | 27.62 |
| Surin | North-East | 6.24 | 7.10 | 15.86 | 161.54 | 2.00 | 1.91 | 5.65 | 47.47 |
| Nakhon Ratchasima | North-East | 58.16 | 2.24 | 37.70 | 129.51 | 18.68 | 0.60 | 13.43 | 38.06 |
| Buriram | North-East | 9.67 | 5.88 | 44.50 | 214.88 | 3.11 | 1.58 | 15.85 | 63.14 |
| **Total (seasonal)** | | **492.93** | | **1,405.56** | | **154.51** | | **447.61** | |
| **Total (by adoption per year)** | | **1,898.49** | | | | **602.12** | | | |
| **Total (annual)** | | **2,500.61** | | | | | | | |

**Table 7. GHG emissions from non-megafarms in the 5th year with 60% adopted interventions by province, season and irrigation condition**

(IR=Irrigated; RF=Rain-Fed)

| Province | Region | GHG emissions ($ktCO_2e$/season) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Category 1: 60% adopted | | | | Category 2: 40% non-adopted | | | |
| | | Dry | | Wet | | Dry | | Wet | |
| | | IR | RF | IR | RF | IR | RF | IR | RF |
| Chiang Mai | North | 5.93 | 0.63 | 14.30 | 9.28 | 4.56 | 0.47 | 13.32 | 7.70 |
| Chiang Rai | North | 3.30 | 4.24 | 19.71 | 12.79 | 2.53 | 3.12 | 18.37 | 10.61 |
| Uthai Thani | Central Plains | 13.13 | 7.71 | 29.88 | 26.12 | 12.01 | 5.73 | 34.72 | 21.89 |
| Nakhon Sawan | Central Plains | 17.41 | 17.52 | 35.47 | 31.01 | 15.92 | 13.02 | 41.22 | 25.99 |
| Kamphaeng Phet | Central Plains | 24.46 | 6.83 | 27.51 | 24.05 | 22.37 | 5.07 | 31.96 | 20.15 |
| PhiChit | Central Plains | 17.37 | 16.56 | 38.69 | 33.83 | 15.89 | 12.31 | 44.97 | 28.35 |
| Phitsanulok | Central Plains | 30.58 | 15.76 | 29.85 | 26.11 | 27.97 | 11.72 | 34.69 | 21.87 |
| Lop Buri | Central Plains | 23.97 | 0.99 | 26.43 | 23.11 | 21.93 | 0.74 | 30.71 | 19.36 |
| Chainat | Central Plains | 21.72 | 1.41 | 42.97 | - | 18.31 | 1.06 | 39.54 | - |
| Ang Thong | Central Plains | 22.49 | - | 35.16 | - | 18.95 | - | 32.35 | - |
| Pathum Thani | Central Plains | 39.96 | - | 51.46 | - | 33.67 | - | 47.34 | - |
| Sing buri | Central Plains | 27.36 | - | 40.72 | - | 23.05 | - | 37.46 | - |
| Ayuthaya | Central Plains | 37.99 | - | 48.70 | - | 32.01 | - | 44.80 | - |
| Suphan buri | Central Plains | 25.87 | 0.61 | 36.39 | - | 21.80 | 0.46 | 33.48 | - |
| Si sa ket | North-East | 8.92 | 2.13 | 17.70 | 12.02 | 7.64 | 1.53 | 16.82 | 9.42 |
| Kalasin | North-East | 24.14 | 0.57 | 17.78 | 12.08 | 20.67 | 0.41 | 16.90 | 9.47 |
| Ubon Ratchathani | North-East | 19.24 | 1.42 | 24.38 | 16.56 | 16.48 | 1.02 | 23.16 | 12.97 |
| Roi Et | North-East | 2.45 | 4.40 | 21.82 | 14.82 | 2.10 | 3.16 | 20.73 | 11.61 |
| Surin | North-East | 0.86 | 0.98 | 17.47 | 11.86 | 0.74 | 0.70 | 16.59 | 9.30 |
| Nakhon Ratchasima | North-East | 10.67 | 0.41 | 20.95 | 14.23 | 9.14 | 0.30 | 19.90 | 11.15 |
| Buriram | North-East | 2.08 | 1.27 | 38.85 | 26.39 | 1.78 | 0.91 | 36.91 | 20.68 |
| **Total (Seasonal)** | | **463.35** | | **930.44** | | **391.25** | | **876.46** | |
| **Total (by adoption per year)** | | **1,393.79** | | | | **1,267.71** | | | |
| **Total (annual)** | | **2,661.50** | | | | | | | |

**Table 8. Aggregated GHG emissions in the 5th year by farm-type, season and irrigation condition with adopted rate of 80% for megafarms and 60% for non-megafarms**

(IR = Irrigated; RF = Rain-Fed)

| Farm-type | GHG emissions ($ktCO_2e$) | | | |
|---|---|---|---|---|
| | Dry season | | Wet season | |
| | IR | RF | IR | RF |
| Megafarms | 508.92 | 138.52 | 527.36 | 1,325.81 |
| Non-megafarms | 709.45 | 145.15 | 1,272.12 | 534.79 |
| **Total (by irrigation condition per season)** | **1,218.37** | **283.67** | **1,799.48** | **1,860.60** |
| **Total (seasonal)** | **1,502.04** | | **3,660.08** | |
| **Total (annual)** | **5,162.12** | | | |

**Table 9. GHG mitigation potential in the 5th year by farm-type, season and irrigation condition with adopted rate of 80% for megafarms and 60% for non-megafarms**

(IR = Irrigated; RF = Rain-Fed)

| Province | Region | GHG mitigation ($ktCO_2e$) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Megafarm (80% adoption) | | | | Non-Megafarm (60% adoption) | | | |
| | | Dry season | | Wet season | | Dry season | | Wet season | |
| | | IR | RF | IR | RF | IR | RF | IR | RF |
| Chiang Mai | North | 0.78 | 0.06 | 7.47 | 0.92 | 0.91 | 0.07 | 5.69 | 2.27 |
| Chiang Rai | North | 0.87 | 0.77 | 9.01 | 7.19 | 0.50 | 0.45 | 7.84 | 3.13 |
| Uthai Thani | Central Plains | 2.25 | 0.41 | 6.21 | 4.31 | 4.88 | 0.89 | 22.20 | 6.71 |
| Nakhon Sawan | Central Plains | 6.13 | 1.91 | 11.62 | 11.59 | 6.47 | 2.02 | 26.36 | 7.97 |
| Kamphaeng Phet | Central Plains | 5.19 | 0.45 | 8.98 | 4.34 | 9.10 | 0.79 | 20.44 | 6.18 |
| PhiChit | Central Plains | 5.79 | 1.71 | 18.04 | 10.14 | 6.46 | 1.91 | 28.75 | 8.69 |
| Phitsanulok | Central Plains | 9.47 | 1.51 | 12.76 | 7.30 | 11.37 | 1.81 | 22.18 | 6.71 |
| Lop Buri | Central Plains | 5.66 | 0.07 | 15.91 | 2.73 | 8.92 | 0.11 | 19.64 | 5.94 |
| Chainat | Central Plains | 3.98 | 0.13 | 9.99 | 1.05 | 5.73 | 0.18 | 16.33 | - |
| Ang Thong | Central Plains | 0.52 | - | 1.17 | - | 5.94 | - | 13.36 | - |
| Pathum Thani | Central Plains | 3.71 | - | 6.87 | - | 10.55 | - | 19.55 | - |
| Sing buri | Central Plains | 1.66 | - | 3.55 | - | 7.22 | - | 15.47 | - |
| Ayuthaya | Central Plains | 4.05 | - | 7.47 | - | 10.03 | - | 18.50 | - |
| Suphan buri | Central Plains | 7.08 | 0.08 | 10.84 | 2.76 | 6.83 | 0.08 | 13.83 | - |
| Si sa ket | North-East | 14.72 | 0.97 | 4.51 | 23.19 | 2.54 | 0.17 | 7.53 | 2.11 |
| Kalasin | North-East | 6.40 | 0.04 | 3.56 | 2.95 | 6.87 | 0.05 | 7.56 | 2.12 |
| Ubon Ratchathani | North-East | 12.63 | 0.26 | 3.90 | 12.31 | 5.47 | 0.11 | 10.37 | 2.90 |
| Roi Et | North-East | 2.41 | 1.19 | 5.34 | 16.49 | 0.70 | 0.34 | 9.28 | 2.60 |
| Surin | North-East | 1.77 | 0.56 | 6.74 | 28.33 | 0.24 | 0.08 | 7.43 | 2.08 |
| Nakhon Ratchasima | North-East | 16.54 | 0.18 | 16.03 | 22.71 | 3.03 | 0.03 | 8.91 | 2.50 |
| Buriram | North-East | 2.75 | 0.46 | 18.92 | 37.68 | 0.59 | 0.10 | 16.52 | 4.63 |
| **Total (seasonal)** | | **125.11** | | **384.89** | | **123.53** | | **384.25** | |
| **Total (by farm-type per year)** | | **507.19** | | | | **507.78** | | | |
| **Total (annual)** | | **1,017.79** | | | | | | | |

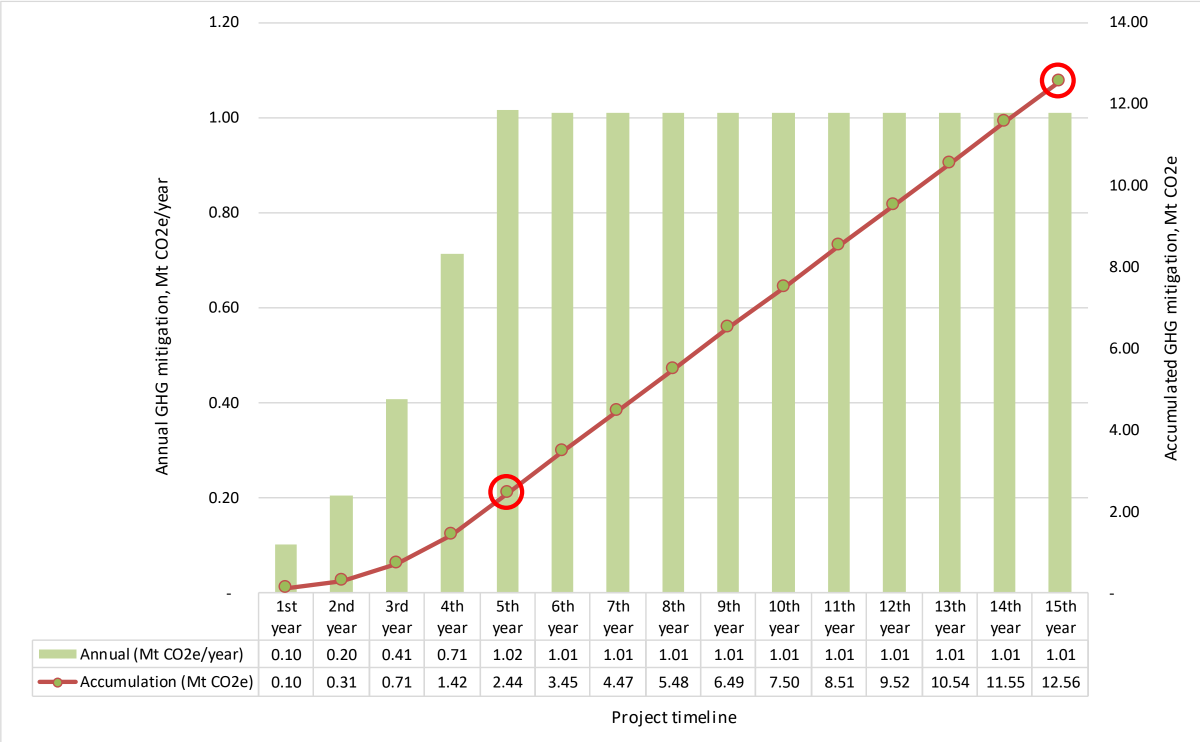


**Figure 1. Annual and Cumulative GHG Mitigation Potential over Project Lifetime**

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## Supporting Data

Baseline and target adoption rate of climate-smart technologies by region

| Region | Irrigated land (%) | Season length (day) | Water management (% area)* | | | | Nitrogen rate (kg/ha) | Residue management (% weight)** | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Irrigated | | | Rain-fed | | Irrigated | | | Rain-fed | | |
| | | | CF | SA | AWD | RF | | Bur | Inc. | Rem | Bur | Inc. | Rem |
| **Baseline: Dry season** | | | | | | | | | | | | | |
| North | 61 | 120 | 100 | - | - | 100 | 77 | 20.3 | 11.3 | 68.4 | 26.2 | 21.5 | 52.3 |
| North-Central | 60 | 120 | 50 | 50 | - | 100 | 96 | 20.3 | 11.3 | 68.4 | 26.2 | 21.5 | 52.3 |
| Central | 98 | 107 | 7 | 33 | 60 | 100 | 96 | 35.9 | 25.8 | 38.3 | 18.3 | 26.4 | 55.3 |
| North-East | 65 | 125 | 75 | 25 | - | 100 | 77 | 1.1 | 47.7 | 51.2 | 21.2 | 17.6 | 61.2 |
| **Baseline: Wet season** | | | | | | | | | | | | | |
| North | 52 | 145 | 100 | - | - | 100 | 85 | 10.2 | 55.7 | 34.2 | 13.1 | 60.8 | 26.2 |
| North-Central | 35 | 145 | 70 | 30 | - | 100 | 107 | 10.2 | 55.7 | 34.2 | 13.1 | 60.8 | 26.2 |
| Central | 92 | 112 | 6 | 19 | 75 | 85 | 107 | 18.0 | 62.9 | 19.2 | 9.2 | 63.2 | 27.7 |
| North-East | 12 | 150 | 70 | 30 | - | 100 | 85 | 0.6 | 73.9 | 25.6 | 10.6 | 58.8 | 30.6 |
| **Target: Dry season** | | | | | | | | | | | | | |
| North | 61 | 120 | 70 | 30 | - | 100 | 77 | 20.3 | 11.3 | 68.4 | 26.2 | 21.5 | 52.3 |
| North-Central | 60 | 120 | 7 | 33 | 60 | 100 | 86 | 20.3 | 11.3 | 68.4 | 26.2 | 21.5 | 52.3 |
| Central | 98 | 107 | - | - | 100 | 100 | 86 | 35.9 | 25.8 | 38.3 | 18.3 | 26.4 | 55.3 |
| North-East | 65 | 125 | 50 | 25 | 25 | 100 | 77 | 1.1 | 47.7 | 51.2 | 21.2 | 17.6 | 61.2 |
| **Target: Wet season** | | | | | | | | | | | | | |
| North | 52 | 145 | 50 | 50 | | 100 | 85 | 10.2 | 48.0 | 41.9 | 13.1 | 48.0 | 38.9 |
| North-Central | 35 | 145 | 6 | 19 | 75 | 100 | 96 | 10.2 | 48.0 | 41.9 | 13.1 | 48.0 | 38.9 |
| Central | 92 | 112 | - | - | 100 | 100 | 96 | 18.0 | 48.0 | 34.1 | 9.2 | 48.0 | 42.9 |
| North-East | 12 | 150 | 50 | 25 | 25 | 100 | 85 | 0.6 | 48.0 | 51.5 | 10.6 | 48.0 | 41.4 |

*CF = continuous flooding; SA = single aeration; AWD = Alternate Wetting and Drying

**Bur = burning; Inc = incorporation; Rem = Removal

Emission and scaling factors used in the GHG modelling

| Parameter | Description | Value | Unit | Source / Rationale |
|---|---|---|---|---|
| Scaling factor for water regime before the cultivation period | Non-flooded <= 180 days<br>Non-flooded > 180 days | 1.00<br>0.89 | N/A | IPCC, 2019 |
| Scaling factor for water regime during the cultivation period relative to continuously flooded fields | Continuously flooded<br>Single drainage period<br>Multiple drainage periods<br>Rain-fed (regular rain-fed) | 1.00<br>0.71<br>0.55<br>0.54 | N/A | IPCC, 2019 |
| Scaling factor for duration of straw incorporation | Short (<= 30 days)<br>Long (> 30 days) | 1.00<br>0.19 | N/A | IPCC, 2019 |
| Emission factor of $CH_4$ | Default value of $CH_4$ emissions from soil for South-East Asia | 1.22 | kg $CH_4$/ha/day | IPCC, 2019 |
| Emission factor of $N_2O$ | Percentage of direct $N_2O$ emissions from N fertilizer under:<br>· Continuously flooded<br>· Intermittent irrigation<br>· Non-flooded<br><br>Indirect $N_2O$ emissions from the nitrification and denitrification processes that transform some of the $NH_4^+$ and $NO_3^-$ to $N_2O$<br><br>$CO_2$ equivalence of emissions generated to produce 1kg of N fertilizer | 0.3<br>0.5<br>1.0<br><br>0.001<br><br>4.77 | % (or converted to kg $N_2O$-N/kg N)<br><br>kg $N_2O$-N/kg N<br><br>kg $CO_2$e/kg N | IPCC, 2019<br><br>IPCC 2006<br><br>Ex-ACT (FAO, 2022, DOI:10.4060/cc0142en) |
| Emission factor of straw burning | $CO_2$ equivalence of methane and nitrous oxide emitted from straw burning | 144.57 | kg $CO_2$e/t straw | Romasanta et al (2016) |

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**IRRI** aims to improve livelihoods and nutrition, abolishing poverty, hunger and malnutrition among those who depend on rice-based agri-food systems. In doing so, IRRI's work protects the health of rice farmers and consumers, and the environmental sustainability of rice farming in a world challenged by climate change. IRRI's work promotes the empowerment of women and supports opportunities for youth in an equitable agri-food system.

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