Appendix C: Supplemental Guidance for Monitoring Methods and GHG Emission Calculations

This appendix provides additional explanations for the monitoring parameters and methods used in this methodology. Project participants have a certain degree of freedom to select the monitoring methods depending on the situation. This appendix also explains the procedures how to calculate CH_4 and N_2O emissions in specific cases regarding the success of water management. This methodology makes much of the results.

1. Selection of representative fields in each stratum

The 3 representative fields in terms of environmental and agronomic settings need to be prepared for both project and reference areas in every stratum. This is to avoid over- or under-estimation of the calculated CH_4 emission reduction. A pair of project and reference fields should be provided from one farmer to avoid the effect of historical difference in agronomic practice on the CH_4 emission and rice yield. Each of the 3 paired fields should have the same agronomic history for ≥5 year.

2. Significant rice yield reduction

Rice yield sampling is implemented at the total of 6 representative fields in each stratum to confirm that there is no rice yield reduction by the project. For the direct seeding system, 1 m × 2 m area should be selected from each field whereas a rectangle area with 50 rice hills for the transplanting system. Unhulled rice grain yield with the same moisture content needs to be measured. A sampling area with normal rice growth should be visibly selected at harvest.

The 95% confidence interval (CI) of the yield in 3 fields needs to be calculated for both project and reference areas. If the intervals do not overlap each other, it is considered that there is significant change in rice yield.

The lower and upper limits of 95% CI is calculated using the CONFIDENCE.T function in Excel as follows:

Lower limit = $Y_m - CONFIDENCE.T(0.05, STDEV.S(Y_1, Y_2, Y_3), 3)$

Upper limit = $Y_m + CONFIDENCE.T(0.05, STDEV.S(Y_1, Y_2, Y_3), 3)$

Where:

$Y_m, Y_1, Y_2, and\ Y_3$ are the mean rice yield of the 3 fields, rice yield at the first field, rice yield at the second field, and rice yield at the third field, respectively.

3. Water level monitoring

It is necessary to submit photos of monitored water level with location and time information as well as a logbook for the water level and/or the number of drained days. In specific cases listed in Table C-1, daily rainfall data recorded using an on-site weather station or at the nearest metrological station also need to be provided to ensure that the water level during non-monitoring days is within the allowed range. Remote sensing can be an option to monitor water existence (>0 cm) and non-existence (≤0 cm) when project participants demonstrate its accuracy and reliability enough to be applied to independent experts described in Appendix A in advance. In addition to remote sensing, other improved methods to monitor water level could be considered to be applied when the independent experts approve those by reviewing the submitted base data in advance.

There are several required timings of taking photos: (1) when the water level reaches −15 cm, (2) when the water level maintains ≤0 cm for a total of 10 days consisting of at least 3 consecutive days (e.g., 3 d + 3 d + 4 d and 4 d + 6 d) in case of using the number of drained days as the index, (3) when the water level reaches ≤0 cm for the first time, and (4) at least 3-day interval while the water level maintains ≤0 cm.

There are 4 cases of water level change to decide which timing photos should be taken (Table C-1). In every scenario, it is strongly recommended to take photos of the water level on the first day when the water level reaches under the soil surface to secure flexibility in case the water level does not reach −15 cm, These “first day photos” must be taken in Case II and III.

*SFw of single drainage is applied in Case II and III even if these cases are achieved more than one time. However, SFw of multiple drainage can be applied in Case II or III subject to combination of Case I.

*Logbook must be recorded appropriately in all the cases to support the data.

*The examples in Table C-1 are representatives and do not cover all the cases.

Table C-1. Four cases of taking photos

<table>
<tr><th>Case</th><th>Scenario, condition, and required photos</th></tr>
<tr><td>I</td><td>Expected water level: −15 cm.
Result: water level −15 cm achieved.
Applicable only in case that the water level previously reached −15 cm in the same rice season at the same area.
➢ Photos taken when the water level reaches −15 cm.
<table>
<tr><td>Day</td><td colspan="5">Any date</td></tr>
<tr><td>Water</td><td><0</td><td><0</td><td><0</td><td><0</td><td>-15</td></tr>
</table>
</td></tr>
</table>

Level					
Photo	(X)				X

II

Expected water level: −15 cm.

Result: water level −15 cm not achieved.

Applicable only in case that the water level previously reached −15 cm in the same rice season at the same area.

- Principle:

  Photos taken when the water level reaches ≤0 cm for the first time. Photos taken at least once every 3 days while the water level maintains ≤0 cm. The water level needs to maintain ≤0 cm for the total of 10 days consisting of at least 3 consecutive days.

Example

Day	1	2	3	4	5	6	7	8	9	10
Water Level	<0	<0	<0	<0	<0	<0	<0	<0	<0	<0
Photo	X			X			X			X

- Alternatives:

  Photos taken when the water level reaches ≤0 cm for the first time and taken to prove that the water level remains below the soil surface when the total of 10 days have passed since the first day of the water level reaching ≤0 cm. The water level needs to maintain ≤0 cm for the total of 10 days consisting of at least 3 consecutive days. The days in between two photos are deemed the water level remaining below the soil surface consecutively, as long as the rainfall data indicates no rainfall during the period.

Example A

Day	1	2-9	10
Water Level	<0	<0	<0
Photo	X	No rainfall (proved by data)	X

Example B

Day	1	2-5	6	7	8	9*	10*	11
Water Level	<0	<0	**<0**	**>0**	<0	<0	<0	<0
Photo	X	No rainfall	X	Rainfall	X			X

		(proved by data)						

*The water level can be deemed below the soil surface for day 9 and 10 as these days are between day 8 and day 11 where photos are taken once every 3 days to indicate the water level <0 (see the Principle of Case II).

Example C

Day	1	2-5*	6	7	8	9	10	11	12
Water Level	<0	<0	**>0**	**>0**	<0	<0	<0	<0	<0
Photo	X	No rainfall (proved by data)	Rainfall		X			X	X

*When there is appropriate rainfall data as well as logbook records, this period (day2-5) can be deemed the water level below the soil surface. A photo of the first day of the water level reaching below the soil surface again (day 8) must be taken for the record of the following days.

III

Expected water level: below the soil surface but above −15 cm.

Result: water level −15 cm not achieved.

Applicable also in case that the previous water level data are not available.

- Principle:

  Photos taken when the water level reaches ≤0 cm for the first time. Photos then taken at least once every 3 days while the water level remains ≤0 cm. These photos prove that the water level remains ≤0 cm for the total of 10 days consisting of at least 3 consecutive days.

Example

Day	1	2	3	4	5	6	7	8	9	10
Water Level	<0	<0	<0	<0	<0	<0	<0	<0	<0	<0
Photo	X			X			X			X

- Alternatives:

  Photos taken when the water level reaches ≤0 cm for the first time and taken to prove that the water level remains below the soil surface when total of 10 days have passed since the first day of the water level reaching ≤0 cm. The water level needs to maintain ≤0 cm for the total of 10 days consisting of at least 3 consecutive days. The days in between two photos are deemed the water level remaining below the soil surface consecutively, as long as the rainfall data indicates no rainfall during the period.

Example A

Day	1	2-9	10
Water Level	<0	<0	<0
Photo	X	No rainfall (proved by data)	X

Example B

Day	1	2-5	6	7	8	9	10	11
Water Level	<0	<0	**<0**	**0>**	<0	<0	<0	<0
Photo	X	No rainfall (proved by data)	X	Rainfall	X			X

*The water level can be deemed below the soil surface for day 9 and 10 as these days are between day 8 and day 11 where photos are taken once every 3 days to indicate the water level <0 (see the Principle of Case III).

Example C

Day	1	2-5*	6	7	8	9	10	11	12
Water Level	<0	<0	**>0**	**>0**	<0	<0	<0	<0	<0
Photo	X	No rainfall (proved by data)	Rainfall		X			X	X

*When there is appropriate rainfall data as well as logbook records, this period (day 2-5) can be deemed the water level below the soil surface. A photo of the first day of the water level reaching below the soil surface again (day 8) must be taken for the record of the following days.

IV

Expected water level: below the soil surface but above −15 cm.
Result: water level -15cm achieved.
Applicable also in case that the previous water level data are not available.

- Photos taken when the water level reaches −15 cm.

Day	Any date				
Water Level	<0	<0	<0	<0	-15
Photo	(X)				X

4. Calculation of CH_4 emission reduction by the direct measurement

Calculation methods for CH_4 emission reduction by the direct measurement differ year by year. In the years when the direct measurement is implemented, the measured $EF_{CH4,R,s,d,st}$ or $EF_{CH4,P,s,d,st}$ need to be used for the calculation. On the other hand, in the years when the direct measurement is not implemented, the mean $EF_{CH4,R,s,d,st}$ or $EF_{CH4,P,s,d,st}$ of the previous ≥3-year measurements need to be used. The minimum frequency of the direct measurement is once per 5 years after the 3-year initial measurements to derive the initial $EF_{CH4,R,s,d,st}$ or $EF_{CH4,P,s,d,st}$. The examples 1 and 2 of Table C-2 show 3-year interval measurement. More frequent measurements are available as shown in the example 3 (once per 2 years) or every year. If the initial measured $EF_{CH4,R,s,d,st}$ or $EF_{CH4,P,s,d,st}$ are not reasonable for project participants due to abnormal weather conditions and/or poor water management, additional measurement is possible to derive the initial $EF_{CH4,R,s,d,st}$ or $EF_{CH4,P,s,d,st}$ as shown in the example 4. After the initial measurements, if the measured $EF_{CH4,R,s,d,st}$ or $EF_{CH4,P,s,d,st}$ are out of the 95% confidence interval of the previous measured means, $EF_{CH4,R,s,d,st}$ or $EF_{CH4,P,s,d,st}$ need to be recalculated by adding the newly measured means as shown in the examples 2 and 3. The examples of the schedule for the direct measurement of 5-year and 4-year intervals are shown in Table C-3.

Table C-2. Examples of schedule for the direct measurement at 3-year interval

Year	Example 1	Example 2	Example 3	Example 4
Before	Meas	No meas	No meas	Meas
Y1	Meas	Meas	Meas	Meas
Y2	Meas	Meas	Meas	Meas (bad weather)
Y3	Calc (B12)	Meas	Meas	Additional meas
Y4	Calc (B12)	Calc (123)	Calc (123)	Calc (B13)
Y5	Meas (in)	Calc (123)	Meas (in)	Calc (B13)
Y6	Calc (B12)	Meas (out)	Calc (123)	Meas (in)
Y7	Calc (B12)	Calc (1236)	Meas (out)	Calc (B13)
Y8	Meas (in)	Calc (1236)	Calc (1237)	Calc (B13)
Y9	Calc (B12)	Meas (out)	Meas (in)	Meas (in)
Y10	Calc (B12)	Calc (12369)	Calc (1237)	Calc (B13)

* B: Before, Meas: Measurement, No meas: No measurement, Calc: Calculation.

*The figures in the parentheses indicate years used to calculate the mean $EF_{CH4,R,s,d,st}$ or $EF_{CH4,P,s,d,st}$ (ex: Calc (B13): Calculate the mean $EF_{CH4,R,s,d,st}$ or $EF_{CH4,P,s,d,st}$ using the data from the year "B"efore the project, the "1"st year, and the "3"rd year).

*Meas (in/out): This indicates whether the result of the measurements is within or out the 95% confidence interval of the previous measured mean.

Table C-3. Examples of schedule for the direct measurement at 5-year and 4-year intervals.

Year	Example 5 (5-year)	Example 6 (5-year)	Example 7 (5-year)	Example 8 (4-year)
Before	Meas	No meas	Meas	No meas
Y1	Meas	Meas	Meas	Meas
Y2	Meas	Meas	Meas (bad weather)	Meas
Y3	Calc (B12)	Meas	Additional meas	Meas
Y4	Calc (B12)	Calc (123)	Calc (B13)	Calc (123)
Y5	Calc (B12)	Calc (123)	Calc (B13)	Calc (123)
Y6	Calc (B12)	Calc (123)	Calc (B13)	Calc (123)
Y7	Meas (in)	Calc (123)	Calc (B13)	Meas (out)
Y8	Calc (B12)	Meas (out)	Meas (in)	Calc (1237)
Y9	Calc (B12)	Calc (1238)	Calc (B13)	Calc (1237)
Y10	Calc (B12)	Calc (1238)	Calc (B13)	Calc (1237)

In parentheses, the year numbers used to calculate the mean $EF_{CH4,R,s,d,st}$ or $EF_{CH4,P,s,d,st}$.

5. Calculation of CH_4 emission reduction by the IPCC factors

Calculation of CH_4 emission reduction by the IPCC's tier-1 and tier-2 factors requires the direct measurement at least once per 5 years to confirm its appropriateness. The year starting the direct measurement can be chosen from that before the project (before) or the first year (Y1) as shown in the examples I and II of Table C-4. However, the project area needs to be fixed before starting the project when using the example I. The conservative $EF_{CH4,R,s,d,st}$ and SF_w should be derived and used to calculate the CH_4 emission reduction as shown in Table C-5. If the measured $EF_{CH4,R,s,d,st}$ and/or SF_w are too conservative and not reasonable for project participants due to abnormal weather condition and/or abnormal agronomic practices, additional measurement is possible as shown in the examples III and IV of Table C-4.

Table C-4. Examples of schedule for the direct measurement for the calculation using the IPCC's tier-1 and tier-2 factors.

Year	Example I	Example II	Example III	Example IV
Before	Meas			

Y1		Meas	Meas	Meas
Y2			Additional meas	
Y3				
Y4				
Y5	Meas			
Y6		Meas	Meas	Meas
Y7				Additional meas
Y8				
Y9				
Y10				

Table C-5. Procedures to decide the $EF_{CH4,R,s,d,st}$ and SF_w used for the calculation.

Order	Procedure
1	Calculate the 95% confidence interval (CI) of both the measured $EF_{CH4,R,s,d,st}$ and SF_w*.
2	Compare the 95% CI of the measured $EF_{CH4,R,s,d,st}$ and SF_w with the 95% CI of the tier-2 $EF_{CH4,c,s,d}$ ** and tier-1 SF_w***, respectively.
3-1	If the 95% CI of the measured $EF_{CH4,R,s,d,st}$ and the 95% CI of tier-2 $EF_{CH4,c,s,d}$ overlap, the tier-2 $EF_{CH4,c,s,d}$ needs to be used.
3-2	If the 95% CI of the measured $EF_{CH4,R,s,d,st}$ and the 95% CI of tier-2 $EF_{CH4,c,s,d}$ do not overlap and the measured $EF_{CH4,R,s,d,st}$ exceeds the interval, the tier-2 $EF_{CH4,c,s,d}$ needs to be used.
3-3	If the 95% CI of the measured $EF_{CH4,R,s,d,st}$ and the 95% CI of tier-2 $EF_{CH4,c,s,d}$ do not overlap and the measured $EF_{CH4,R,s,d,st}$ falls short of the interval, the measured $EF_{CH4,R,s,d,st}$ needs to be used.
4-1	If the 95% CI of the measured SF_w and the 95% CI of SF_w overlap, the tier-1 SF_w needs to be used.
4-2	If the 95% CI of the measured SF_w and the 95% CI of SF_w do not overlap and the measured SF_w falls short of the interval, the tier-1 SF needs to be used.
4-3	If the 95% CI of the measured SF_w and the 95% CI of SF_w do not overlap and the measured SF_w exceeds the interval, the measured SF_w needs to be used.

* SF_w is calculated as follows:

$$SF_w = \frac{SF_{w1} + SF_{w2} + SF_{w3}}{3}$$

Where:

SF_{w1} = The ratio of CH_4 emission from the first paired project field to CH_4

emission from the first paired reference field.

SF_{w2} = The ratio of CH_4 emission from the second paired project field to CH_4 emission from the second paired reference field.

SF_{w3} = The ratio of CH_4 emission from the third paired project field to CH_4 emission from the third paired reference field.

The lower and upper limits of 95% CI of SF_w is calculated using the CONFIDENCE.T function in Excel as follows:

Lower limit = $SF_w - CONFIDENCE.T(0.05, STDEV.S(SF_{w1}, SF_{w2}, SF_{w3}), 3)$

Upper limit = $SF_w + CONFIDENCE.T(0.05, STDEV.S(SF_{w1}, SF_{w2}, SF_{w3}), 3)$

The same procedure applies to the calculation of 95% CI of EF.

** The original error range provided to tier-2 EF is that between the minimum and maximum values among the seasonal data used to derive the mean [Tracking Greenhouse Gases: An Inventory Manual, 2011 (pdf file, 3.6 MB)]. This methodology therefore recalculated the 95% CI of tier-2 EF with referring its source articles (Corton et al., 2000; Wassmann et al., 2000) as follows:

EF for dry season rice: 1.46 (95% CI, 1.08−1.84) (kg ha^{-1} d^{-1})

EF for wet season rice: 2.95 (95% CI, 1.97−3.92) (kg ha^{-1} d^{-1})

Project participants need to use these intervals to decide the EF used for the calculation of CH_4 emission reduction by the IPCC's factors.

*** IPCC's tier-1 SF_w and its 95% CI are as follows:

SF_w for multiple drainage: 0.55 (95% CI, 0.41−0.72)

SF_w for single drainage: 0.71 (95% CI, 0.53−0.94)

6. Spatial heterogeneity of water management

It is unrealistic to uniformly implement water management across all the project fields, due to factors other than stratification parameters such as different elevation, different soil permeability, and different water availability. This may cause the spatial heterogeneity of the success of water management. For example, it could happen that multiple drainage events are achieved in the representative project fields in which the direct measurement is implemented, whereas only one drainage event is achieved in other many project fields, and vice versa.

Because the former causes the overestimation of CH_4 emission reduction, it is necessary to calculate it in a conservative manner. In the case of the direct measurement, the CH_4 emission reduction by single drainage should be estimated by multiplying the measured CH_4 emission reduction by the conversion ratio derived from IPCC's SF_w

[(1−0.71)/(1−0.55) = 0.29/0.45]. On the other hand, for the latter case, the measured CH_4 emission reduction by single drainage needs to be applied to all the project fields.

In the case of the calculation using the IPCC's factors, SF_w suitable to the actual situation (i.e., 0.55 or 0.71) should be used combinationally.

7. Unexpected change from multiple drainage to single drainage

It is difficult to accurately predict the success of water management before starting the season. For example, no or only one drainage event can be achieved due to intermittent rainfalls throughout the season even in case when farmers originally aimed for multiple drainage events. There are two unexpected changes in the planned drainage practice. One is the change from the planned multiple drainage to the resultant single drainage (M to S), and another is the opposite change that from the planned single to the resultant multiple (S to M). Project participants need to decide suitable SF_w following the procedures described in Table B-1.

Table B-1. Four cases to decide SF_w used for the calculation.

Case	Procedure
M to S with the direct measurement	The measured SF_w is used in that year/season. Additional measurement is possible to derive suitable calculated SF_w of multiple drainage as shown in Tables C-2 and C-3.
M to S without the direct measurement	The calculated or teir-1 SF_w of multiple drainage needs to be corrected by multiplying by 0.29/0.45.
S to M with the direct measurement	The measured SF_w is used in that year/season. However, this SF_w cannot be directly used to derive the calculated SF_w of single drainage. Instead, the measured SF_w needs to be corrected by multiplying by 0.29/0.45 for this purpose.
S to M without the direct measurement	The calculated or teir-1 SF_w of single drainage needs to be used in a conservative manner.

8. N_2O emission factor not affected by the success of water management

The description in the above sections 6 and 7 is not applied to the calculation of N_2O emission. This is because the current IPCC's N_2O emission factor (EF_{1FR}) does not distinguish between single drainage and multiple drainage. That is, the same EF_{1FR} is used without regard to the number of drainage events achieved (i.e., one or more). This is true for the direct measurement. The measured $EF_{N2O,R,s,st}$ is used in that year/season and the calculated $EF_{N2O,R,s,st}$ is derived from the previous ≥3-year measurements without regard to the number of drainage events achieved. It is possible but not necessary to implement additional measurement for deriving suitable $EF_{N2O,R,s,st}$.