INITIATIVE FOR CLIMATE ACTION TRANSPARENCY PROJECT: SET UP OF SECTORAL MRV SYSTEMS FOR THE AGRICULTURE SECTOR

Fiji Agriculture Rice Cultivation Emissions

Inventory Manual

DISCLAIMER

PREPARED UNDER

Initiative for Climate Action Transparency (ICAT) supported by the German Federal Ministry for the Environment, Nature Conservation, and Nuclear Safety, the Children´s Investment Fund Foundation, the Italian Ministry for Ecological Transition, and ClimateWorks.

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Acronyms

BY	Base year
C	Carbon
CH4	Methane
CO2	Carbon dioxide
CO2e	Carbon dioxide equivalent
COP	Conference of Parties to the United Nations Framework Convention on Climate Change
EF(s)	Emission Factors
FAO	Food and Agriculture Organization
FAOSTAT	Food and Agriculture Organization Corporate Statistical Database
FBoS	Fiji Bureau of Statistics
GWP	Global Warming potential
kg	Kilogram
kt	Kilotonnes
MOA	Ministry of Agriculture
MRV	Measurement, reporting and verification
N O	Nitrous oxide

Preface

This manual is derived from the cumulative experience from work during Initiative for Climate Action Transparency project: Set up of sectoral MRV systems for the agriculture sector. It takes off from the 2006 Intergovernmental Panel on Climate Change (IPCC) Guidelines for National Greenhouse Gas Inventories, Good Practice and Uncertainty Management in National Greenhouse Gas Inventories 2000. It is also informed by scientific literature specific to the Fiji case, where available.

The manual is organised by sub-sectors of Rice cultivation under Agriculture, Land-Use Change, and Forestry. It is intended for use by personnel who will be involved in generating GHG emissions data to be used for the inventory, from government such as the Ministry of Agriculture, and the Fiji Bureau of Agricultural Statistics, among others. The Manual focuses on providing a guide to the process for emissions under rice cultivation.

Introduction

Rice (*Oryza sativa*) is one of the world's most important food crop. It forms the staple diet of a very large proportion of the world's population. Currently, in Fiji, rice is an important staple food substituted with root crops. Rice contributed to the improvement of the livelihood of many farmers and their family members who rely on rice as the main source of income. Therefore, in Fiji rice has multi-dimensional roles in food security and economic growth. Rice has been a major source of food for all ethnic groups in Fiji, with per capita consumption reaching 75 kg per year, an increase of up to 29 percent over the level in 2000 (Bong,2017). Further, rice has contributed to the improvement of the livelihoods of thousands of farmers and their family members who rely on rice as a main source of income. Therefore, in Fiji, rice has a multi-dimensional role as the foundation of food security, economic growth, as well as social and political stability.

Unfortunately, the Fiji rice industry has been increasingly weakened over the years as the rice area and production declined while the rice yield growth has been stagnant or marginal. Consequently, Fiji, which attained nearly 70 percent of self-sufficiency in rice in the 1980s has had to import more than 80 percent of the total rice demanded annually. This is a dilemma because the agro-climatic conditions in Fiji are favourable except for rice cultivation. In 2019, Fiji imported $42 million worth of rice from different countries whereby most of the rice imported was supplied by Vietnam. It is anticipated that this trend will continue to increase considering the increase in population and preference for rice.

The Government of Fiji (Government) is highly determined to revitalize its rice industry with the establishment the National Rice Taskforce in September 2004 to steer and coordinate the country's rice revitalization program efforts to strengthen rice production toward reducing rice imports and achieving self-sufficiency in rice. Since then, the Government has given supportive policies and incentives along with increased investment from public and private sectors to promote the rice industry development.

Rice production systems contribute to global climate change through emissions of carbon dioxide (CO_2), methane (CH_4), and N_2O gases to the atmosphere and simultaneously are affected by the changed climatic variables. Rice paddy fields act as a source of greenhouse gases such as methane (CH_4) and nitrous oxides (N_2O) depending on soil organic matter status, land use and cropping intensity, irrigation water, and drainage management practices, soil microbial populations and their activities, soil properties, and climatic variables. The management practices such as tillage operations, leveling, plant residue incorporation, irrigation frequency and standing water levels, drainage system, and organic and inorganic soil amendments followed in rice farming influence the amount of CH_4 and N_2O emitted to the atmosphere. Generally, CH_4 gas is produced under flooded or anoxic soil conditions while N_2O gas is produced through nitrification and denitrification processes depending on soil aerobic (oxygenated) and anaerobic conditions Rice cultivation, for instance, also emits methane (CH_4) depending on where the rice cultivation occurs, and the CO_2 emissions contribute to the global warming which will eventually further exacerbate the existential crisis caused by rising sea levels that confronts so many island communities. This document reviews the current emissions from the Fiji rice industry and elaborates on feasible options for mitigation in the future.

1. Rice production in Fiji

Rice has been grown in Fiji for a little over a century. It is cultivated in Fiji before the arrival in Fiji of Indians in 1879. The Indian laborers on sugar cane plantations expanded rice cultivation for family subsistence. The colonial government in the 1930s and 1940s started Fiji's first official rice development programs in response to the low sugar prices and high imports of rice. Since 1960, the rice area was expanded to the non-sugar land, and specialised areas to grow rice was formed in the Northern, Central and Western Divisions. After Independence in 1970, there was another drive for self-sufficiency and this led to the establishment of large-scale (by Fijian standards) irrigation schemes for rice at Lakena and Navua (Central Division) and at Dreketi (Northern Division) in the 1970s, a total of 11 irrigation schemes in the Central and Northern Divisions were established. Along with the construction of irrigation schemes, several rice development projects were implemented, including the Northern Rice Development Project under

Australian Aid in the North, the Agricultural Development Project (ADP) in the Central Division, and the Improvement of Rice Cultivation Technology Project (IRCTP) under Japanese Aid (JICA) at Koronivia Research Station. During the 1980s the Government continued applying several policy measures to encourage rice production, which led to a steep increase in rice production since the mid-1980s and Fiji attained 75 percent of self-sufficiency in rice. Peak production was achieved in 1989 and 1989 at around 30 000 tonnes of paddy rice per year. In the late 1980s, the Government changed the policy on rice development by applying deregulation, removal of input subsidies (agro-inputs, machines, water, etc.), neglecting investment for infrastructure maintenance, and at the same time facilitation of rice imports. These adverse policies immediately resulted in negative impacts on the rice industry as the rice area and production started declining and simultaneously rice imports increased.

The major rice-growing areas in Fiji are the Northern, Western, and Central Divisions, of which the Northern Division is the rice bowl of the country. Data from Fiji National Agricultural Census (2020) showed rice production was predominated by the North Division, while in the Central Division rice production was almost negligible (Table 1). In 2010, the distribution of rice production was as follows: 80 percent of the production was from the North, 15 percent from the West and 5 percent, in the Central Division. The decrease in rice production in the Central Division was due to the damage to irrigation schemes so farmers have converted rice to other dryland crops. In the Northern Division, rice is mainly grown in rural areas of western Macuata and Bua Province. The main production areas are in the Dreketi Irrigation Project areas, sugar cane belt areas of Macuata, Nasarawaqa, Korokadi Irrigation Projects areas, and in the Bua flats. In the Central Division, rice is mainly concentrated within Navua areas which are managed by Grace Road Food Company Ltd including small-scale farmers scattered within the division. For the Western Division, rice production areas depend on rainfed conditions. Generally, the main areas in the West are, Ra Province, the Northern, and Western region of Ba Province, and portions of the Nadroga/Navosa Province. There are a total of 1,740 rice farmers throughout the province of Bua, Cakaudrove, Macuata, Serua/Namosi, Tailevu, Rewa, Ra and Ba.

Table 1: Fiji Rice Production trend table

Commodity	Division	Production (Mt)										
		2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019[p]
Rice	Central	66	65	53	249	99	177	115	399	605	2,073	615
	Northern	11,507	7,283	7,517	4,051	6,426	5,871	5,922	7,857	8,342	4,966	5,058
	Western	64	315	343	353	348	795	292	393	135	13	75
	Total	11,637	7,664	7,914	4,653	6,873	6,843	6,329	8,649	8793.2	6257.8	6589.2

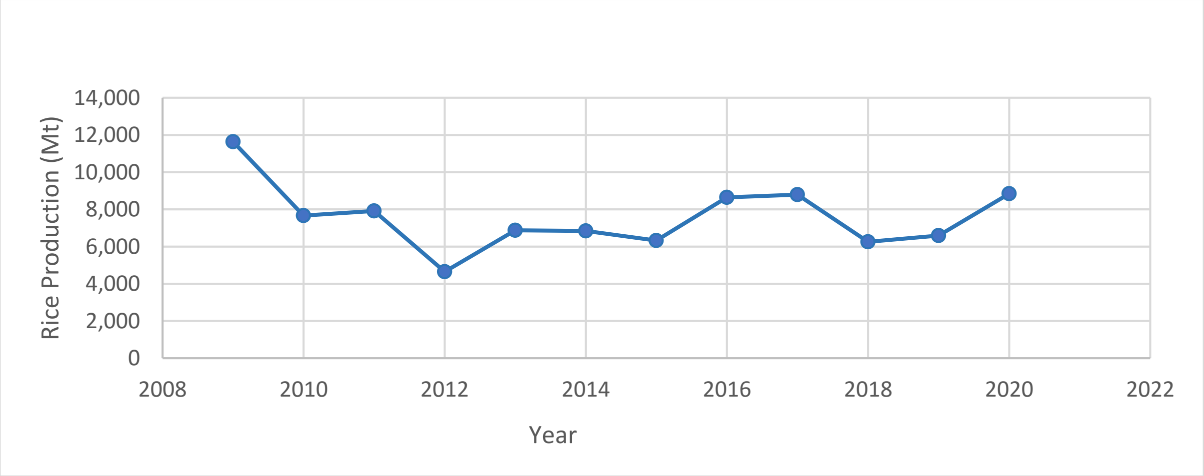
(Data source: Fiji Ministry of Agriculture)

1.1 Rice seasons and ecosystems

The two climatic seasons in a year of Fiji intrinsically have formed the two rice seasons, the main season and offseason. The main rice season is in the wet season with transplanting in October – November, and harvesting from Feb - May. The second rice season or offseason is in the dry season with planting from June – July, and harvesting from September - October. Within the season, rice is grown in the three major ecosystems, namely irrigated, rainfed wetland, and rainfed dry land. From 1994 to 2010 the irrigated ecosystem was formed with the construction of irrigation schemes in the 1970s in the Central Division and the North Division, which accounted for 20 percent of the total rice area. In this ecosystem, two rice crops were produced per year. The rainfed wetland ecosystem is the dominant system of rice production in Fiji, comprising 44 percent of the total rice area. Fields are normally submerged in the water. In some parts of this ecosystem, two rice crops can be grown annually. Rainfed dry land ecosystem located in higher elevation where rice is grown only in the wet season with high rainfall or intercropped with other dry land crops like sugar cane. This ecosystem is comprised 36 percent of the total rice area.

1.2 Long-term trends in rice production in Fiji

Data on rice area, production, and yield in Fiji in the last ten years (2009-2019) were present in Figure 1 and Table 2 (Data source: Fiji Ministry of Agriculture). The rice area and production in Fiji in the period of 2009-2019 decreased as compared to those in the 2000s. In this period, the rice area fluctuated from 1,803 ha in 2012 to 3,355 ha in 2011, the production varied from 4,658 tonnes in 2012 to 7,914 tonnes in 2011, and the yield fluctuated from 2.00 tonnes/ha in 2015 to 3.19 tonnes/ha in 2013. Total rice production in 2018 was 6257.8 tonnes from 2,350 ha. Currently, 70% of farmers have an average land size of 0.8 ha with a minimum land size of 0.4ha. There are about 20% of farmers with rice land between 2 – 4ha and 10 % with more than 4ha. (Draft Rice policy 2021)



(Source: Fiji Ministry of Agriculture)

Figure 1: Fiji Rice Production from 2009 to 2020

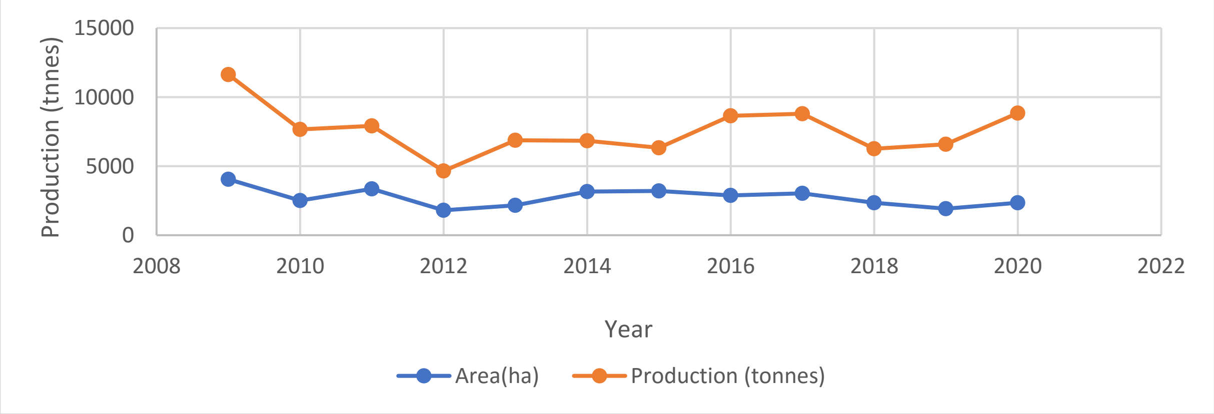


Figure 2: Fiji Rice Production from 2009 to 2020 (Data source: FAOSTAT and Ministry of Agriculture)

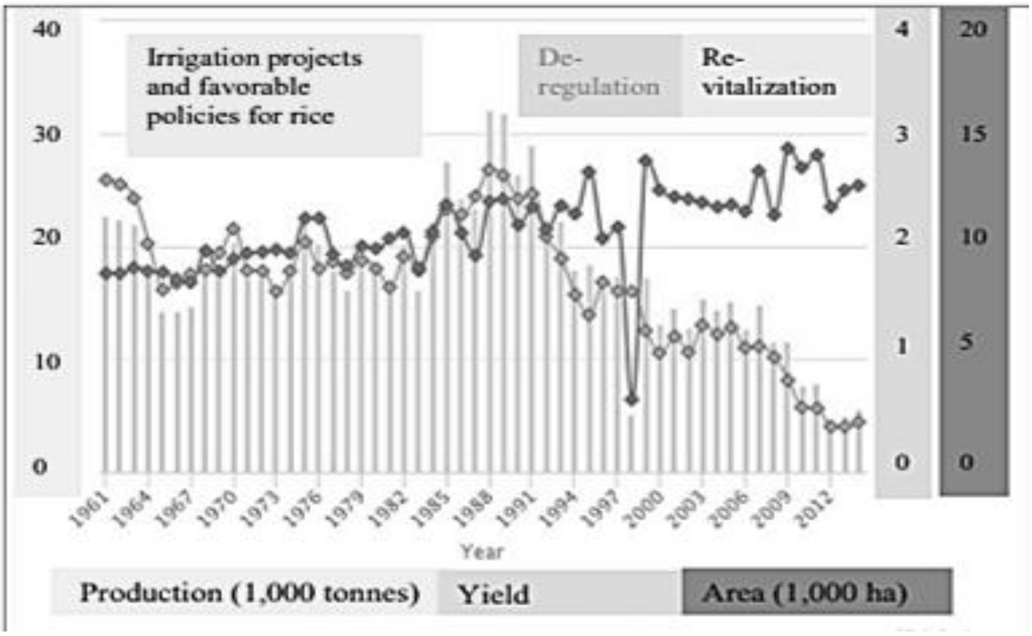


Figure 3. Trends of rice production, area, and yield in Fiji (1961-2014)
Source: Ricepeidia (CGIAR/IRRI) and Bong,2017 FAO (Based on FAO data)

Data on rice area, production, and yield in Fiji in the last six years (2010-2020) were present in Table 2 and Figure 3 on Trends of rice production, area, and yield in Fiji (1961-2014). The rice area, production, and yield in Fiji in the period 2010-2015 decreased as compared to those in the 2000s. In this period, the rice area fluctuated from 2156 ha in 2013 to 1916 ha in 2019, the production varied from 6873 tonnes in 2013 to 6589.2 tonnes in 2019, and the yield fluctuated from 2.00 tonnes/ha in 2019 to 3.19 tonnes/ha in 2013. In 2016, it is recorded that the rice area increased as compared to the previous years, but in 2013-2019, the lowest yield was recorded in 2015. The low yield levels, as 2.0-2.5 tonnes/ha in four of six recent years are a matter of concern in the revitalization of Fiji's rice industry.

Fiji used the Tier 1 approach because methane emissions from rice cultivation aren't a significant source and country-specific emission factors aren't available. The methane emissions from rice production were calculated using equations 5.1 and 5.3 from chapter 5.5 of volume 4 of the 2006 IPCC Guidelines.

Table 2: Fiji Rice Area, Production, and Yield trend for the past 10 years

Year	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Area (ha)	2507	3355	1803	2156	3156	3200	2883	3027	2350	1916	2345
Production (tonnes)	7663	7914	4653	6873	6843	6329	8649	8793.2	6257.8	6589.2	8847
Yield (tonnes/ha)	3.01	2.36	2.58	3.19	2.20	2.0	3	3	3	3	3.7

Source: Annual Crop and Livestock production report 2021 -Economic Planning & Statistics Division and Bong ,2017 FAO

2.0 Calculating Greenhouse Gas Emissions in Fiji

Four worksheets are used for calculating greenhouse gas emissions from this sector. Each worksheet has several component sheets needed to complete the calculations. These are listed below.
Activities under 3C are subdivided into:

- Biomass Burning (3C.1)
- Liming (3C.2)
- Urea application (3C.3)
- Direct N2O emissions from managed soil (3C.4)
- Indirect N2O emissions from managed soil (3C.5)
- Rice cultivations (3C.7)

Rice cultivation, for instance, also emits methane (CH_4) depending on where the rice cultivation occurs (ecosystem – upland rice, irrigated rice, and rainfed rice). The three types of rice farming systems practiced in Fiji depend on the availability of water resources and topography. These three systems are irrigated, rainfed wetland, and rainfed dryland which are planted with recommended varieties such as *Sitara*, *Cagivou*, Star, *Boldgrain,* and *NuiNui*. Most of the CH_4 emissions are from rainfed and irrigated rice cultivation based on the rice flooding regime.

3.0 Methane emission from rice fields

One of the most significant causes of CH_4 emission is anaerobic conditions in wetland rice fields caused by soil submergence. In flooded rice fields, decomposition of organic material releases methane (CH_4), which escapes to the atmosphere mostly through vascular transport through the rice plants. Crop duration, water regimes, and organic soil amendments all contribute to the amount of CH_4 emitted annually from a given area of rice. By multiplying the seasonal emission factors by the annually harvested areas, the CH_4 emissions are calculated. For each sub-unit (state), the harvested area will be multiplied by the emission factor that represents the conditions that define the sub-unit (state). The total annual emissions are equal to the sum of emissions from each sub-unit of the harvested area using the following equation

$$CH_4\ \text{Rice} = S\ i,j,k\ (EFi,\ j,\ k \bullet Ai,\ j,\ k \bullet 10\text{-}6) \qquad (1)$$

Where CH_4 Rice = annual methane emissions from rice cultivation, Gg CH_4 yr-1; EFijk = a seasonal integrated emission factor for i, j, and k conditions, kg CH_4 ha-1; Aijk = annual harvested area of rice for i, j and k conditions, ha yr-1; i, j and k = represent different ecosystems, water regimes, type and amount of organic amendments, under which CH_4 emissions from rice may vary. Separate calculations were undertaken for each rice ecosystem (i.e., irrigated, rainfed, and deep water rice production).

The baseline emission factor is scaled for organic amendments and water regime in rice ecosystems according to the equation (2) given below

$$EFi = EFc \bullet SFw \bullet SFp \bullet SFo \qquad (2)$$

EFi = adjusted seasonal emission factor for a particular harvested area (state) EFc = baseline emission factor for continuously flooded fields without organic amendments. A baseline emission factor for no flooded fields for less than 180 days before rice cultivation and continuously flooded during the rice cultivation period without organic amendments (EFc) is used as a starting point. The IPCC 2006 default for EFc is 1.30 kg CH_4 ha-1 day-1 (with error range of 0.80 - 2.20). SFw = scaling factor to account for the differences in water regime during the cultivation period. SFp = scaling factor to account for the differences in water regime in the preseason before the cultivation period SFo = scaling factor for both type and amount of organic amendment applied. (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. The scaling factor should be based on the application rate of organic amendment and also its conversion factor.

Uncertainties in methane emission

The uncertainties associated with estimating CH_4 emissions are considerable. Various components, including climate, agronomic techniques, and soil qualities, all contribute to uncertainty. The generation of CH_4 in the soil is influenced by a variety of physical, chemical, and biological features of the soil. Different soil types, rice cultivars utilized, and agronomic procedures of water, fertilizer, and manure management all contribute to uncertainty in emission variables. The duration of different rice types utilized in a state is a source of uncertainty. The most popular cultivar in a given region must be determined based on the area under cultivation as well as expert opinion. This factor will be connected with the greatest amount of uncertainty. The application of organic amendments, particularly rice straw incorporation, might be unpredictable. Uncertainties develop as a result of the non-availability of the harvested area in each rice ecosystem under each water regime and type of organic amendment. When compared to the accuracy of emission factors, activity data is likely to be more reliable.

Assumptions used in calculations

As methane emissions from rice cultivation are not a significant source and country-specific emission factors were also not available, for Fiji currently the Tier 1 approach is applied. Equations 5.1. and 5.3 in chapter 5.5, volume 4 of IPCC 2006 were applied to determine the methane emissions from rice production. Area and production data were taken over from a review of rice production, FAOSTAT, and the Ministry of Agriculture. These data are based on national reports and adjustments made by FAO. FAOSTAT covers the areas of rice cultivation, synthetic fertilizers, enteric fermentation, manure applied to soils, manure left on pasture, manure management, burning – of crop residuals, burning – of savanna, crop residues, and cultivation of organic soils. These data are also subject to an error frame of 30-50%.

According to IPCC,2006 guidelines, the increase in biomass stocks of annual crops in a single year is assumed to equal to biomass losses from harvest and mortality in that same year, thus, there is no net accumulation of biomass carbon stocks. Data on the use of nitrogen fertilizers and urea application were taken from the FAO database 2020. Figure 4 shows the map of Fiji showing rice cultivation in Fiji. (Chand, D. 2018). Mainly rainfed wetland and dryland rice were cultivated . A total of 90 -130 days of cultivation was taken into consideration according to the variety taken. Based on the production data, a rice-straw ratio of 1:2 is assumed to calculate the amount of straw produced. The amount of straw absorbed into the soil is determined based on an equal mass basis equal to the dry weight of the straw.

In Fiji, 60 percent of farmers are planting traditional varieties due to reduced costs, particularly in the use of fertilizer. However, it has low yields and lodges easily due to heavy rain and strong winds.

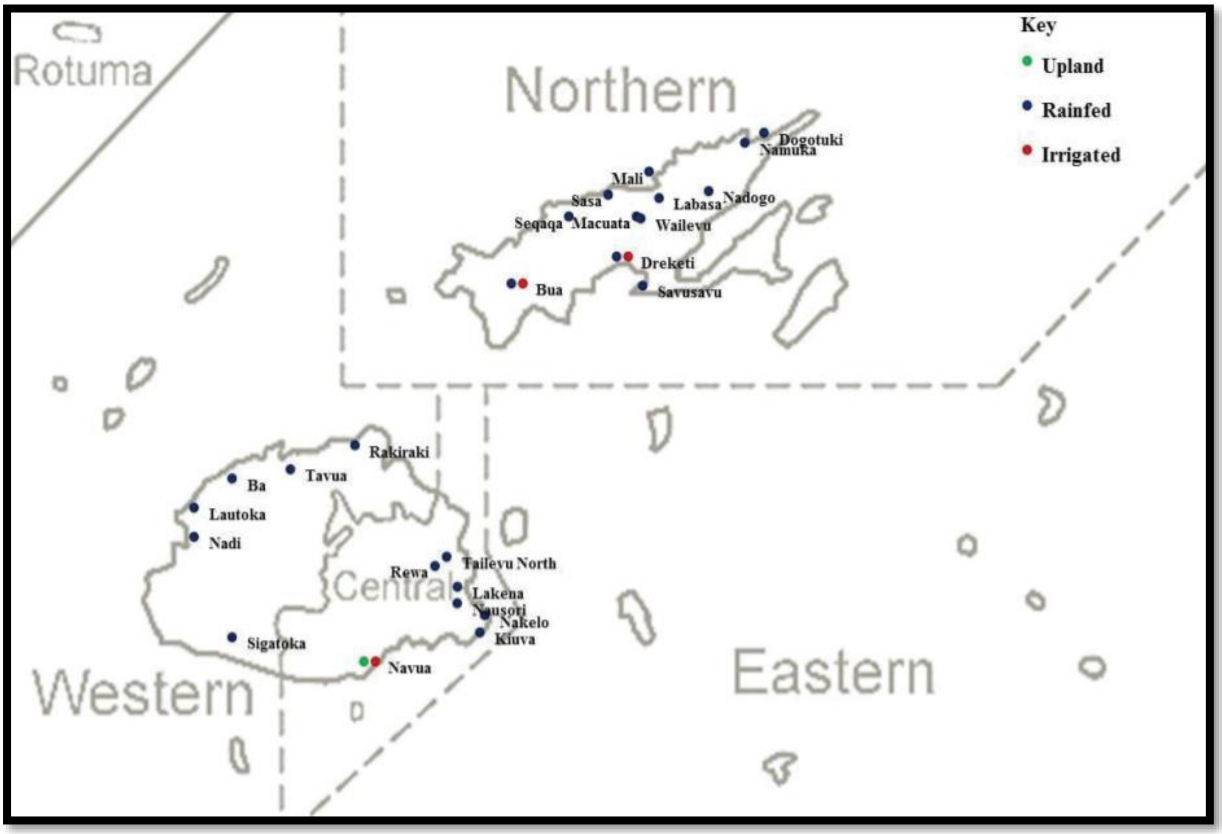


Figure 4: Classification of rice cultivation in Fiji

Rice cultivations and methane emission (3C.7)

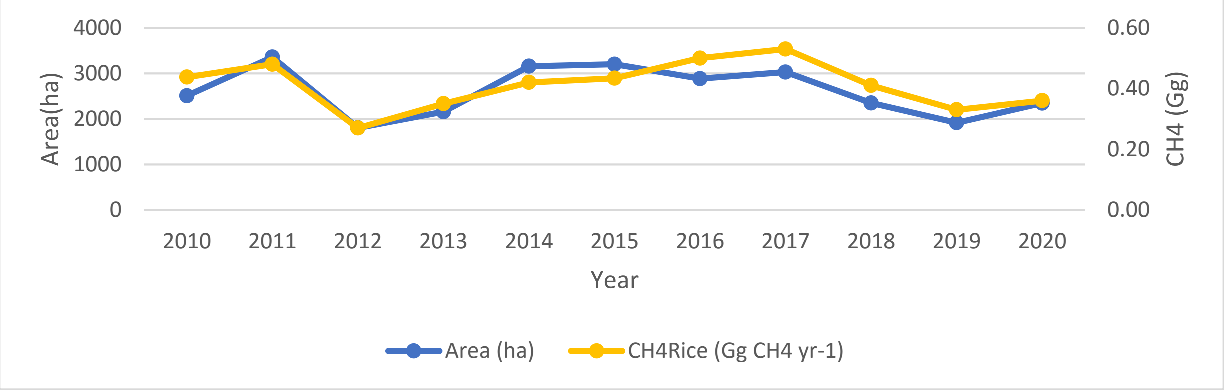


Figure 5: Fiji Rice Methane and Area trend for the past 10 years

Figure 5 shows that the total area of rice planted in Fiji from 2010 to 2020 was 2507 to 2345 ha. The CH_4 emission is positively correlated with the area of cultivation of rice. The lowest was recorded for the year 2012. Lower emission has been attributed to the decrease in the production of rice as a result of crop failure due to crop damage from natural disaster or land issues between farmers and landowners. Secondly, due to the cost of production, the farmers are unable to make profits from the cultivation of rice and thus prefer other cash crops that bring more income. Most of the rice is grown for household consumption in Fiji.

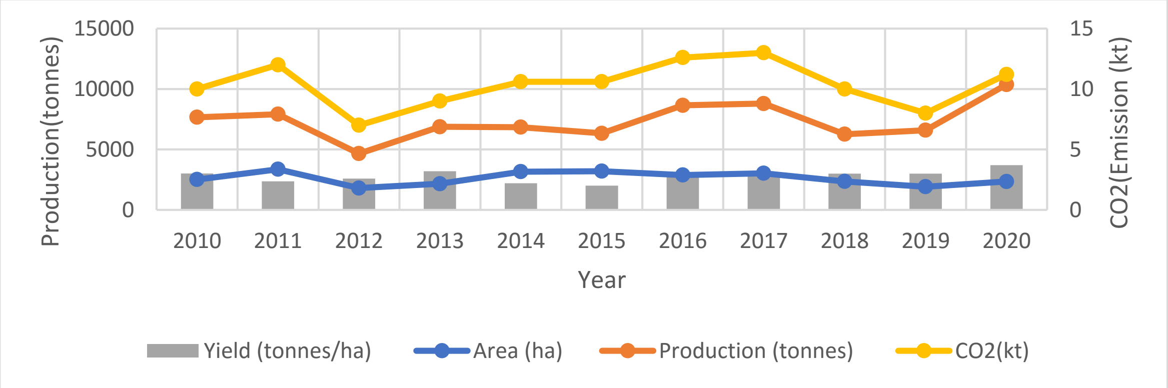


Figure 6: Fiji Rice Production trend for the past 10 years

Data on rice area, production, yield and CO_2 emission in kiloton in Fiji in the last ten years (2010-2019) were present in Figure 6. In this period, the rice area fluctuated from 1,803 ha in 2012 to 3,355 ha in 2011, the production varied from 4,658 tonnes in 2012 to 7,914 tonnes in 2011, and the yield fluctuated from 2.00 tonnes/ha in 2015 to 3.19 tonnes/ha in 2013. Total rice production in 2018 was 6257.8 tonnes from 2,350 ha. CO_2 emission was positively correlated with the production and area, the fluctuation in production were due to crop failure or crop damage due to climatic disasters like flooding, cyclones, drought etc. Irrigated rice fields are the major source of methane from rice fields. Methane production is favored by the assured water supply and control, intensive soil preparation and fertilization, and resultant improved growth of the rice.

Methane emissions are much lower and more variable in rain-fed rice because of drought periods during the growing season and poorer growth of rice. Upland rice is not a source of methane emission because it is not flooded for any significant period**.** Methane production is positively correlated with production and area. Sound and feasible management practices that reduce methane emissions, without enhancing nitrogen losses and increasing rice yields, must be developed.

4.0 Urea application (3C.3)

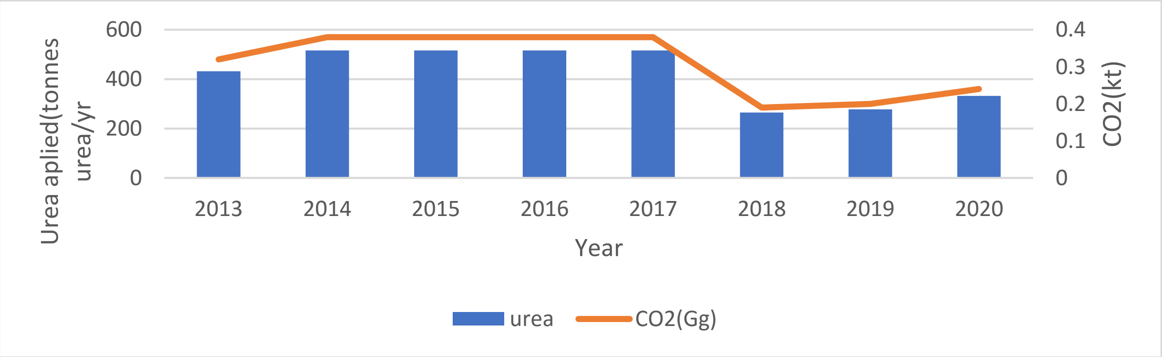


Figure 7: Urea application and emission of CO_2 for the past 10 years

Default values Equation 11.9 from the 2006 IPCC's AFOLU Guidelines is used to estimate the emissions from the use of synthetic fertilizers. Default values (Table 11.3 from the IPCC Guidelines) are used for the emission factors and the volatilization from synthetic fertilizers. The annual amount of synthetic fertilizers applied to soil is taken from FAOSTAT(Figure 7).Urea application is positively correlated with the CO_2 emission , the more application of nitrogenous fertilizer more is the emission.

Since FAOSTAT only provides values until 2013, the average consumption of the years 2006 to 2013 is used to estimate the consumption in the years 2014 and 2015, and the average consumption of the years 2002 to 2015 is used to estimate the consumption in the years 2016 and 2017. Expert opinion from Ministry of Agriculture –Extension officers explained that the urea was not applied from 2001-1994 so the urea consumption data is not available. Ammonium sulphate was applied to rice during that period as reported.

The direct impact of chemical fertilizer applications (table 3) on methane emission is not clear. Because most methane is emitted through the rice plant, improved rice growth (more tiller and roots) in response to fertilizer application increases emission. But source and mode of application may also have direct effects. Sulfate-containing fertilizer reduces methane emissions. Sulfate-reducing bacteria compete with methanogens for the limited hydrogen, but the amount of sulfate normally added as fertilizer seems to be insufficient to have significant effects.

Table 3. N-fertiliser and urea application.

	2006	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**
N-fertiliser application (tonnes)	4,220	4,025	6,758	2,747	2,435	4,101	4,020	3,662	3,996	3,996
Urea (tonnes)	453	458	632	948	453	151	605	432	516	516
Source: Fiji Low Emission Development Strategy,2018										

5.0 Inventory of nitrous oxide emissions from managed soils

Nitrous oxide is produced naturally in soils through the processes of nitrification and denitrification. Nitrification is the aerobic microbial oxidation of ammonium to nitrate, and denitrification is the anaerobic microbial reduction of nitrate to nitrogen gas (N_2). Nitrous oxide is a gaseous intermediate in the reaction sequence of denitrification and a by-product of nitrification that leaks from microbial cells into the soil and ultimately into the atmosphere.

One of the main controlling factors in this reaction is the availability of inorganic N in the soil. This methodology, therefore, estimates N_2O emissions using human-induced net N additions to soils (e.g., synthetic or organic fertilizers, deposited manure, crop residues, sewage sludge), or of mineralization of N in soil organic matter following drainage/management of organic soils, or cultivation/land-use change on mineral soils.

The emissions of N_2O that result from anthropogenic N inputs or N mineralization occur through both a direct pathway (i.e., directly from the soils to which the N is added/released), and through two indirect pathways: (i) following volatilization of NH_3 and NOx from managed soils and fossil fuel combustion and biomass burning, and the subsequent re-deposition of these gases and their products NH_4^+ and NO_3 to soils and waters; and (ii) after leaching and runoff of N, mainly as NO_3, from managed soils. Total emissions of N_2O from managed soils are estimated using equation (3)

Total N_2O- N emission:

$$N_2O\text{-N TOTAL} = N_2O\text{-N DIRECT} + N_2O\text{-N INDIRECT} \qquad (3)$$

Direct emissions of N_2O from managed soils are estimated separately from indirect emissions, though using a common set of activity data. In most soils, an increase in available N enhances nitrification and denitrification rates which then increase the production of N_2O. Increases in available N can occur through human-induced N additions or changes of land-use and/or management practices that mineralize soil organic N

The following N sources will be included in the methodology for estimating direct and indirect N_2O emissions from managed soils:

- Synthetic N fertilizers (FSN)
- Organic N applied as fertilizer (e.g., animal manure, compost, sewage sludge) (FON)
- Urine and dung N deposited as manure (FPRP)
- N in crop residues (above-ground and below-ground), including from N-fixing (FCR)
- N mineralization associated with loss of soil organic matter resulting from the management of mineral soils (FSOM)
- Drainage/management of organic soils (i.e., Histosols) (FOS).

Direct N_2O emissions from managed soil (3C.4)

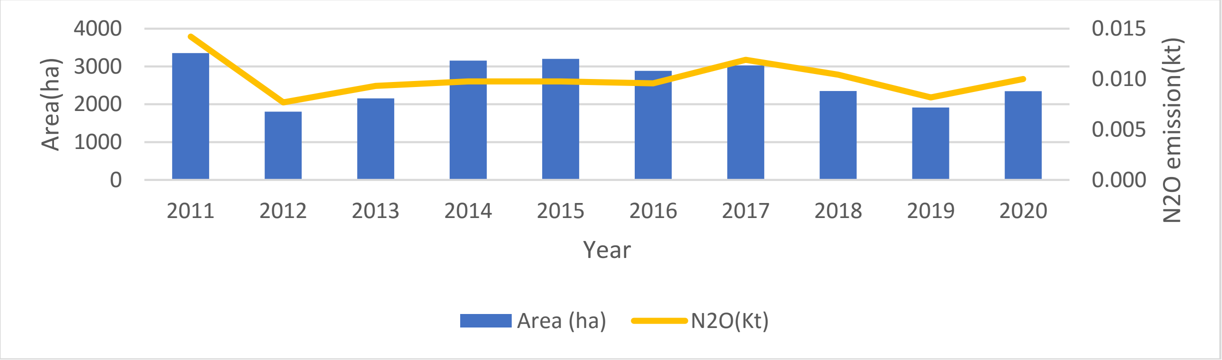


Figure 8: Direct N_2O emissions and area of rice for the past 10 years

Indirect N_2O emissions from managed soil (3C.5)

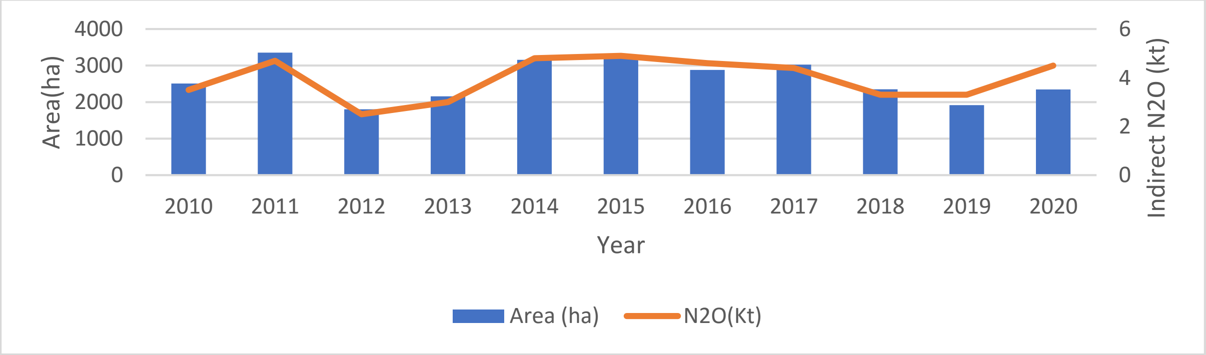


Figure 9: Indirect N_2O emissions and area of rice for the past 10 years

The direct and indirect N_2O emission is positively correlated with the area of cultivation of rice. The lowest was recorded for the year 2012. Lower emission has been attributed to the decrease in the production of rice as a result of crop failure due to crop damage from a natural disaster or land issues between farmers and land owners. Secondly due to cost of production the farmers are unable to make profits from the cultivation of rice and thus prefer other cash crops that bring more income. Most of the rice is grown for household consumption in Fiji.

6.0 Recommendations

Methane (CH_4) and nitrous oxide (N_2O) are the foremost critical greenhouse gases due to their radiative impacts as well as global warming potentials (GWPs). CH_4 and N_2O gasses are at the same time transmitted from rice areas to the air due to their favorable generation, utilization, and transport frameworks. The intensive rice cultivating framework may make over the top weight on rice areas to deliver more rice for the extending populace, subsequently falling apart soil ripeness status and rice paddy biological system adjust by stimulating more CO_2, CH_4, and N_2O fluxes to the environment. Extreme climatic variables such as high light intensity, high water vapor or relative humidity, high temperature, and drought stress can all harm beneficial microbial activity, soil nutrients, and water availability in rice plants. Rice yield may eventually be reduced significantly, while greenhouse gas emissions may increase significantly. Conservation tillage, water-saving irrigation techniques such as alternate wetting and drying, soil amendments with biochar, and vermicompost should be introduced to field-level farmers in this situation to ensure sustainable rice production while reducing greenhouse gas emissions. To effectively reduce CH_4 emissions while maintaining rice yields, an integrated management approach, as well as combinations of mineral nitrogen (N), reduced tillage, a suitable combination of plant residues, and well decomposed manure, i.e., suitable agricultural water and fertilizer management practices, are required. This should not, however, exclude the inclusion of low-cost alternatives that reflect a return to traditional agricultural practices that encourage varied incomes and soil resilience (e.g. intercropping). Water management, rice cultivar selection, nutrient management, and cultivation method are promising approaches to achieve sustainable rice production while reducing GHG emissions from paddy fields. Suitable varieties reduce the risk of crop loss or failure while also ensuring high yields. Therefore, the focus should also be on the field management strategy for lowering soil CH_4 emissions and increasing rice yields.

Table 4. Checklist and detail for data collection for Extension Officer in Rice Division

Checklist(ecosystem)	Data type	Collection of data in Rice field
	Aggregated data	• Number of crops in a year • Duration of crops grown(days)

Irrigated Rice		• Soil type • Air temperature • Rice cultivar • Area • Fertilizer applied • production • Yield (straw yield) • Above ground biomass
	Disaggregated data	• Water regimes before the cultivation period three ecosystem • Water regime during the cultivation period’ • Organic and inorganic soil amendments • Type of drainage for each area • Soil temperature • flooding pattern before and during the cultivation period • Soil pH • Soil Eh (Redox potential)
Rainfed wet land		• Number of crops in a year • Duration of crops grown(days) • Soil type • Air temperature • Rice cultivar • Area • Fertilizer applied • production • Yield (straw yield) • Above ground biomass
		• Water regimes before the cultivation period three ecosystem • Water regime during the cultivation period’ • Organic and inorganic soil amendments • Type of drainage for each area • Soil temperature • flooding pattern before and during the cultivation period • Soil pH • Soil Eh (Redox potential)
Rain fed Dryland Rice		• Number of crops in a year • Duration of crops grown(days) • Soil type • Air temperature • Rice cultivar • Area • Fertilizer applied • production • Yield (straw yield) • Above ground biomass
		• Water regimes before the cultivation period three ecosystem • Water regime during the cultivation period’ • Organic and inorganic soil amendments • Type of drainage for each area

		• Soil temperature • flooding pattern before and during the cultivation period • Soil pH • Soil Eh (Redox potential)

7. Conclusion

This manual outlines which data, emission factors, and computation processes are required and sufficient to generate a simple yet reliable GHG national Inventory for rice farming at Tier 1. Fiji used the Tier 1 strategy since methane emissions from rice agriculture aren't a significant source and country-specific emission factors aren't available. However, if the rice-growing area is large, both irrigated and rainfed, there may be more GHG emissions than in years with smaller rice farm areas. There is a requirement for gathering disaggregated data from rice fields that can be used to calculate Tier 2 or 3 methane emissions from rice productions. More participatory, action-oriented study with farmers is also needed to better understand the situation.

8. References

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9. ANNEXURE

Details for Sources for Activity Data in Fiji

Data Sources	Website
Fiji Bureau of Statistics (FBoS)	https://www.statsfiji.gov.fj/index.php
FAO STAT	http://www.fao.org/faostat/en/#home
Fiji Data source 2020 Census	

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