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Remote Sensing and Model-Based Methane Emission Estimation from Paddy Rice Field over Bangladesh

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Abstract: *Agriculture is estimated to be one of the largest sources of GHG emissions in Bangladesh, estimated at 78 Tera-gram (Tg) carbon di-oxide (CO2)-eq. in 2016, to which rice cultivation contributes approximately 30% of total GHG (CO2-eq.) emitted from agriculture (FAOSTAT, 2018). Rice paddy is a well-known source of methane emission, which accelerated the climate change impacts. Bangladesh as a climate vulnerable country, there is potential to reduce GHG emissions from agriculture. To reduce greenhouse gas emission from rice cultivation, it's very important to proper emission estimation from rice paddy field. In this study, we used remote sensing derived seasonal rice and irrigated rice area map with country adjusted IPCC (IPCC, 2006) model for methane emission estimation from rice paddy field over Bangladesh from 2001 to 2018. There are a numbers of uncertainties to estimate methane emission from rice paddy. In this study we used remote sensing-based rice and irrigated rice area map and IPCC model for methane estimation from rice paddy field in Bangladesh. The result shows that the irrigated Boro rice is the highest methane emission season (218.4 kg CH4 ha^{-1}) and rainfed Amon rice is the lowest methane emission season (55 kg CH4 ha^{-1}). Annually, Boro rice season is the highest methane emission season (1029.44 Gg) followed by Amon (780.91 Gg) and Aus (111.05 Gg) rice growing season in 2018. The methane emission from rice paddy field increased from 1384.97 Gg in 2001 to 1941.21 Gg in 2018. We compare our result with relevant study and found good agreement.*

Objective: The main objective of this study to estimate methane emission from rice paddy field with remote sensing-based seasonal rice and irrigated rice area map and regional adjusted IPCC model over Bangladesh from 2001 to 2018.

01. Data and Methodology

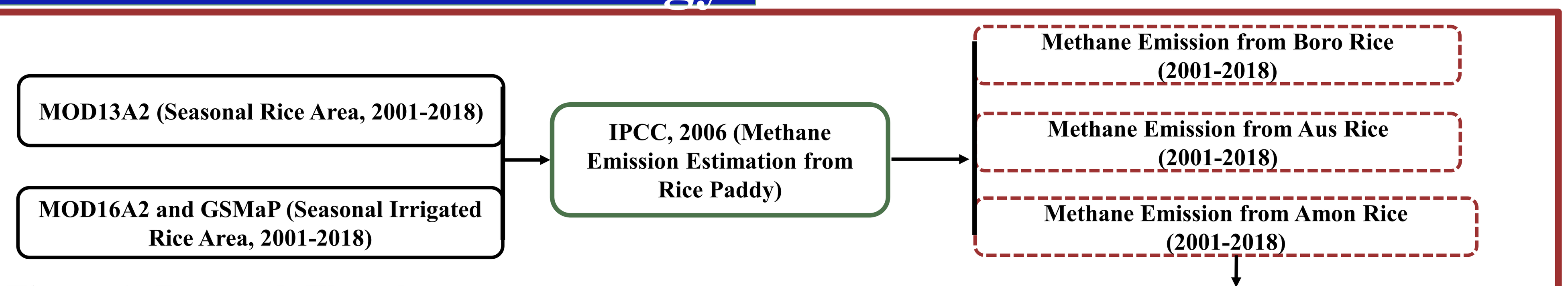

Figure 1: Research Flowchart

$$CH_{4\,Rice} = \sum_{i,j,k} (EF_{i,j,k} \times t_{i,j,k} \times A_{i,j,k} \times 10^{-6}) \quad (1)$$

$CH_{4\,Rice}$ = Annual Methane emission from rice paddy field, Gg CH_4 yr^{-1}

$EF_{i,j,k}$ = Daily Emission factors under i,j,k conditions, kg CH_4 ha^{-1}yr^{-1}

$t_{i,j,k}$ = Cultivation period for i, j, and k conditions, days

$A_{i,j,k}$ = Annual Rice cultivated area under *i, j and k* conditions, yr

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

$$SF_o = [1 + \{(ROA_{i\,RS} \times CFOA_{i\,RS}) + (ROA_{i\,FM} \times CFOA_{i\,FM})\}]^{0.59} \quad (3)$$

$ROA_{i\,RS}$ = Application rate of rice straw (Bor o= 0.70, Aus/Amon = 0.40)

$ROA_{i\,FM}$ = Application rate of Farm manure (0.60)

$CFOA_{i\,RS}$ = Conversion factor for organic amendment (Rice Straw)=1

$CFOA_{i\,FM}$ = Conversion factor for incorporated shortly before cultivation = 0.14

$$EF_i = EF_c \times SF_w \times SF_p \times SF_o \times SF_{s,r} \quad (2)$$

EF_i = Adjusted daily emission factor for cultivated rice area

EF_c = Baseline emission factor without organic amendment (IPCC default value,) 1.30 kgCH4h^{-1}d^{-1}

SF_w = Scaling factor for different water regime (Irrigated =1, Supplementary irrigated = 0.70, rainfed = 0.28)

SF_p = Scaling factor for preseason water regime before cultivation period (default value = 1)

SF_o = Scaling factor for organic amendment (*Boro* = 1.40, *Aus* = 1.31, and *Amon* = 1.26)

$SF_{s,r}$ = **Scaling factor for Soil type, rice cultivar etc. (Not considered in this study)**

Equation 1, 2 and 3 are based on IPCC, 2006 guideline. The parameters value are adjusted based on the rice cultivation characteristics of Bangladesh. The seasonal emission rate is used for; Boro, Aus and Amon season methane emission estimation

02. Result

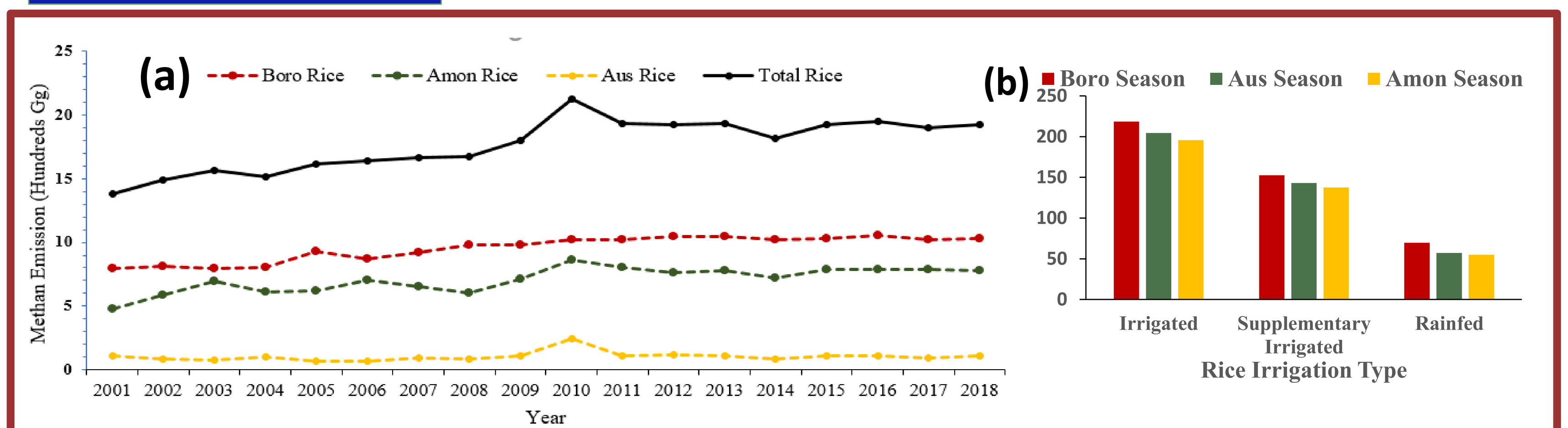

Figure 2: (a) Methane emission from seasonal and annual total rice paddy field of Bangladesh, 2001 to 2018; (b) Seasonal methane emission rate from irrigated, supplementary irrigated and rainfed rice paddy field (in kg ha^{-1})

- The maximum seasonal emission factor in Irrigated Boro rice is 218.4 kg CH4 ha^{-1} and minimum in rainfed Aus season 195.6 kg CH4 ha-1.
- The Annual Boro season estimated methane emission increased 797.49 Gg to 1029.44 Gg from 2001 to 2018 and followed by Amon (481.21 to781.91 Gg) and Aus season (106.26 to111.05 Gg)

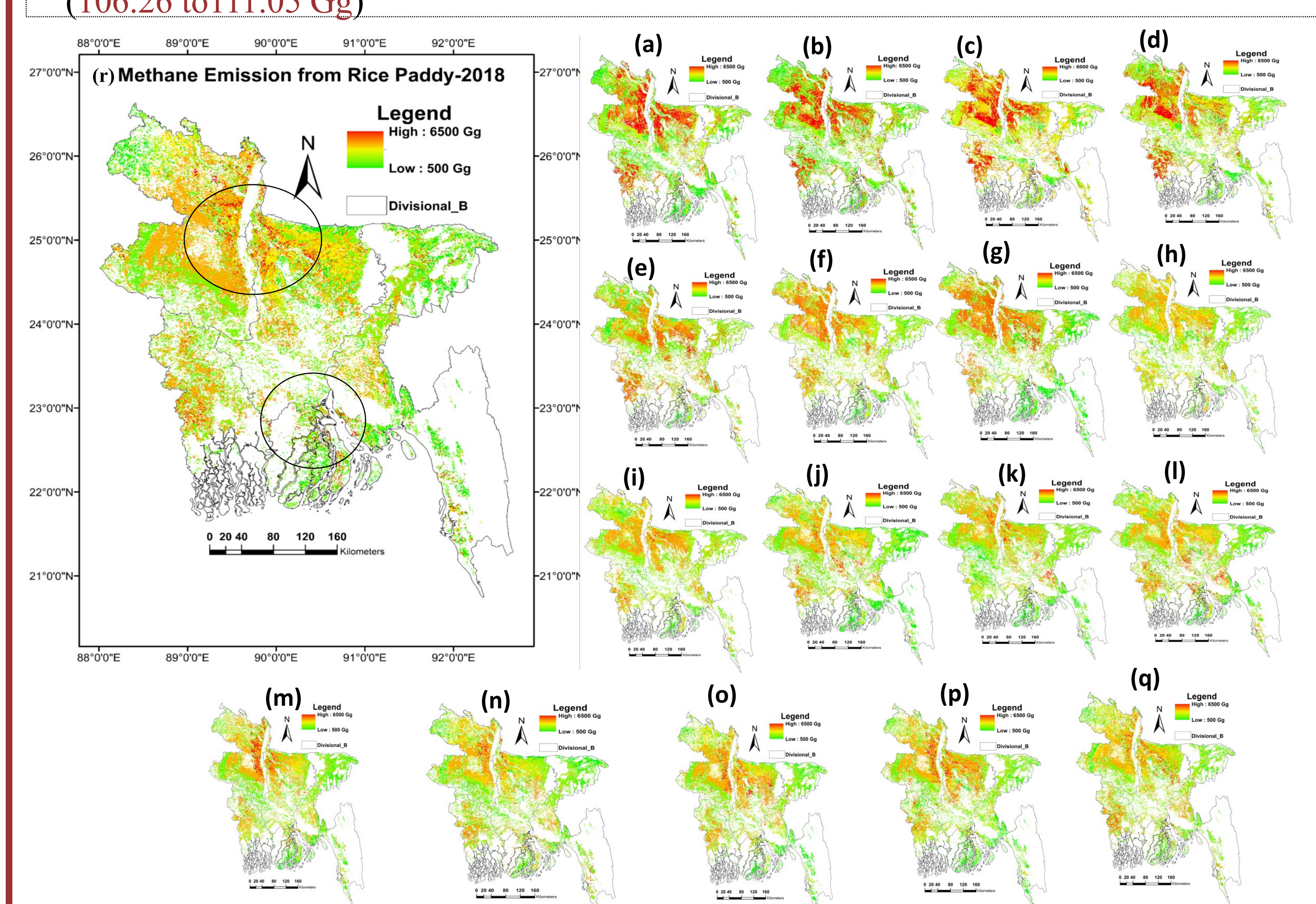

Figure 3: Annual methane emission distribution from rice paddy field of Bangladesh; (a) 2001, (b) 2002, (c) 2003, (d) 2004, (e) 2005, (f) 2006, (g) 2007, (h) 2008, (i) 2009, (j) 2010, (k) 2011, (l) 2012, (m) 2013, (n) 2014, (o) 2015, (p) 2016, (q) 2017 and (r) 2018.

- The Methane emission distribution showed that the central north part of the country is highest emission region and the central-southern part of the country is the lowest emitted region due to the rice cropping patten change single to double and triple rice and irrigation mode.

03. Discussion

Methods	Boro (kgha^{-1}y^{-1})	Aus (kgha^{-1}y^{-1})	Amon (kgha^{-1}y^{-1})
CH4MOD2.5 (Khan and Saleh, 2015)	**99.6 to 116.4**	**-**	**24.48**
DayCent (CF) (Begum, k et. al., 2019)	**150 to 251**		
DayCent (AWD)	**150**	**-**	**-**
CH4 Flux (CF) (Ali, et al., 2017)	**106 to 129**	**-**	**-**
CH4 Flux (AWD) (Ali, et al., 2017)	**90**		
RS_IPCC	69.76 to 218.4	57.2-204.3	55.0-195.6

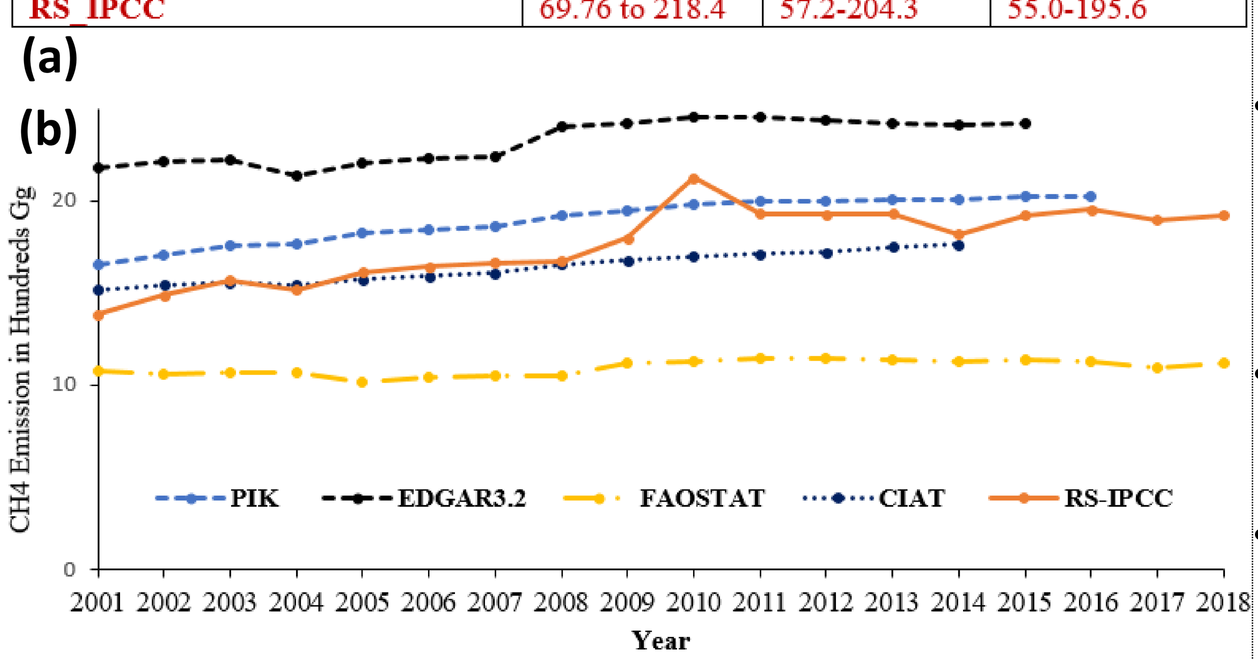

Figure 4: (a) Comparison our RS-IPCC based seasonal emission rate with CH4MOD2.5, DayCent, MODEVAL and field level CH4 flux data.
(b) Comparison of our RS-IPCC based annual methane emission from rice paddy field with FAOSTAT, EDGAR3.2, CIAT and PIK inventory estimation;

- **The seasonal methane emission factor for Boro, Aus and Amon rice from others model and flux-based estimation showed good agreement.**
- **In our study we separately estimated Boro, Aus and Amon season emission factor with Irrigated, Supplementary Irrigated and Rainfed rice.**
- **The Annual estimated methane emission increased with the time.**
- **Our result slightly under-estimated from EDGAR3.2 emission inventory and PIK estimation; and over-estimated from FAOSTAT and CIAT inventory estimation.**

04. Conclusion and Future Work

The highest seasonal CH4 emitted from irrigated Boro (218.4 kg ha^{-1}), and lowest from rainfed Amon rice (55.0 kg ha^{-1}). The annual methane emitted from Boro, Aus and Amon rice are 1029.44 Gg, 780.91Gg and 110.05 Gg respectively. The Annual methane emission was 1384.97 Gg in 2001 and 1941.21 Gg in 2018. The methane emission from rice paddy field in Bangladesh gradually increasing over the time . The annual methane emission increased from 1384.97 Gg in 2001 to 1921.46 Gg in 2018. The rice growing season specific emission factor associated with the different irrigation application used methane emission estimation could be a more reliable tools for emission estimation. In future, we will try to investigated AWD irrigation application-based methane emission estimation.

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