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Study of variations and partitioning of surface energy balance components in rice crop at Odisha, India

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Abstract
Surface energy balance components was measured through eddy covariance technique in rice field over two seasons in Odisha, India (20º17' N, 85º41' E). We examined how surface energy balance components vary on diurnal, seasonal scales and how much amount of energy partitioned into different components *i.e.,* latent heat flux (LH), sensible heat flux (H) and soil heat flux (G) of the total Net radiation (Rn). Results reviled that highest diurnal variation in noon hours and lowest variation was observed in evening hours. Highest seasonal variations was recorded in 2nd growing season at all crop growth stages. The Rn partitioned ratio was highest at LE followed by H and G was minute partitioned during both the cropping season. Our results highlight the importance of adaptive plant responses to seasonal variations in regulating ecosystem energy partitioning and suggest an important role for revegetation, water use efficiency and carbon uptake in study area.

Keywords: Surface energy balance, eddy covariance, net radiation, latent heat, ecosystem, growing season

Introduction
Suns radiation plays a vital role in plant growth, development and production. Plants are the efficient biological converters of solar radiations into biomass. Suns radiation defines the yield of a crop region. Micrometeorological aspects evaluation of energy balance components is very important for researchers who wish to manage and predict of crops grass and forest of specific sowing time, metabolic activities and energy absorptions including other vegetation successfully. Net radiation (Rn) is partitioned into three components namely ground/soil heat flux (G), sensible heat flux (H) and latent heat flux (LE). It shows the amount or proportion of the energy can be utilized to more helpful in understanding for various processes including the evapotranspiration, photosynthesis and convective heat exchange. The incident net radiation is dependent on several factors like height and arrangement of plants, plant structure, leaf angle, plant geometry, leaf size and age of the crop. These are the important parameters (Rn, LE, H and G) which decide the production productivity of the crop. Were, latent heat flux is dominant energy among other component of energy balance (Ding *et al.,* 2013) [5]. Energy evaluation on crops, researchers work on surface energy balance components and practiced at microclimate level measurements had already been done in different parts of the world (Burba *et al.,* 1999; Brammer and Ham, 1999; Bremer *et al.,* 2001; Khatun *et al.,* 2014) [4, 2, 3, 7].
The energy balance at the earth's surface is closely relations with the overlaying near atmospheric boundary layer (Roxy *et al.,* 2014). Bezerra *et al.,* (2014) [11, 1] reported that the energy balance partitioning varies seasonally along with each growth stages of cotton. The energy balance closure is based on conservation of energy. This should lead to the available energy in an agricultural ecosystem equalling the energy involved in the various processes (Pardo *et al.,* 2015) [9]. Surface energy exchange and mass in this important agricultural ecosystem is closely linked with hydrology and water vapour flux, sensible heat flux and soil heat flux are fundamental components. The eddy covariance technique was employed to measure the energy fluxes along with other micrometeorological, plant and soil measurements. In this paper, we assess the energy balance component in study area over two growing seasons of rice crop to determine the fluxes accurately and results on the surface energy partitioning in the rice experiment field in Odisha, India during Kharif seasons 2018 and 2019.

Materials and method
Study area
Experiment was conducted to compute energy balance components over rice crop in Kharif season 2018 & 2019 at farm of ICAR-IIWM, Deras, Mendhasal, Khurdha District of Odisha, India.

Which situated in 20°17’ N latitude, 85°41' E longitude and elevation 86.6 m above sea level.

Climate of study area

The experimental site is under tropical and it is included under Agro-climatic zone “Eastern plateau and Hills Agro-climatic zone-VII”. Average annual rainfall is 1428 mm and receives mainly through South-West monsoon during end of June to October. Summer season is hot humid and sometimes measure crosse 45^0C during May-June. The warmest average temperature was 31.3^0C and lowest was recorded 21.8^0C. Soil of the experimental field has. sandy loam texture and soil moisture % was recorded which varies from 20 to 26.68%. The pH value of the soil ranges from 5.3 to 5.6.

Eddy Covariance flux measurements

EC system consist of a sonic anemometer (CSAT3A, Campbell Scientific Inc., USA) and were continuously measured with the open-path infrared gas analyser (EC150, Campbell Scientific, Inc., NE, USA) and data logger (CR3000; Campbell Scientific Inc., UT, USA), mounted on a tower at 6.2-m height. Site maintenance and sensor calibrations were performed periodically. Raw data from the eddy covariance system were collected at 10 Hz and supporting data were sampled every 10 seconds whereas, we sampled data in every 30-minute using CR3000 data logger.

Determination of surface energy balance

The energy balance of the cropped field can be represented as per the following equation:

$$Rn = G + H + LE + Mi$$

Where,
Rn = net radiation in W/m^2
H = sensible heat flux in W/m^2
LE = latent heat of vaporization in W/m^2
G = ground heat flux in W/m^2
Mi= Miscellaneous, that is used in the physiological process by the crop plants, W/m^2
This parameter is generally neglected since the energy utilized in Mi is less than 1 per cent.
Rn was measured through Net radiometer sensor NR-LITE 2 is used for measuring solar and far infrared radiation balance which is attached in EC tower.

Latent heat flux (LE)

The latent heat flux was calculated using the following formula:

$$LE = (Rn - G) / 1 + \beta$$

Where,
β = Bowen ratio (0.66 x dt/ de)
dt= temperature gradient between two height
de= vapour pressure gradient between two height

Sensible heat flux (H)

Sensible heat flux was calculated by the formula:

$$H = Rn - G - LE$$

H and LE were determined using BREB Method (Rosenberg *et al.*, 1983; Harazono *et al.*, 1999) [10, 6] and direct calculating through EC system. The Bowen ratio (β) was calculated from vertical gradients of air temperature and water vapor pressure, which were measured with temperature-humidity sensors HC2-S3-L measures air temperature with a pt100 RTD and relative humidity based on the Hygroclip2 technology attached in EC tower.

Ground heat flux (G)

Ground heat flux was measured with the help of soil heat flux plates. EC system 109 probe uses a thermistor to measure soil temperature. BetaTherm 10K3A1 Thermistor sensor is used which measure temperature ranges from -50 to +70°C. The output was recorded with the help of data logger.

Results and Discussion

Diurnal variation of energy balance components

The EC system showed that the value of different components of energy balance (Rn, LE, H and G) was higher during the noon hours than that recorded during morning and evening hours for both the crop growing season. It shows more or less same trend in both the season 2018 and 2019. The important crop growth stages (tillering, panicle initiation, flowering and maturity stages) of both the seasons were taken and showed in the fig-1&2, Rn was the highest from 12:00 to 13:00 hrs with the values being 376.04, 357.98, 396.16 and 512.09 Wm^{-2} during 2018 and 487.09, 488.32, 518.98 and 431.80 Wm^{-2} during 2019 in four respective crop growth stages. LE was also highest during 12:00 to 13:00 hrs with the values 141.99, 196.53, 172.06 and 250.79 Wm^{-2} during 2018 and 214.54, 174.45, 293.65 and 280.09 Wm^{-2} during 2019 in four respective crop growth stages. H was also highest during 12:00 to 14:00 hrs with the values being 31.30, 72.10, 64.88 and 121.63 Wm^{-2} during 2018 and 87.28, 80.24, 96.42 and 92.12 Wm^{-2} during 2019 in four respective crop growth stages. Were G was recorded relatively negative values of all respective crop growth stages due to the moist conditions of the field. Results showed the radiation components *i.e.*, Rn, LE, H and G are highest value at maturity stage in 2018 whereas flowering stage showed highest value in 2019. LE was supporting to loss of water in the form of evaporation and consumed some part of energy of the Rn. The sensible heat in the crop field acted as a factor for that transfer towards the atmosphere. The daytime ground heat flux was positive signifying that soil absorbed heat from the atmosphere of both the seasons. The variation was due to changes in the sun angle in a day and seasons also, similar results were recorded by Shamim, 2003 and Samui *et al.*, 2002 [13, 12]. H showed almost zero during mid-day having very small positive values and G showed somewhere negative values of the day time over all ecosystem reported by Khatun *et al.*, 2014 [7].

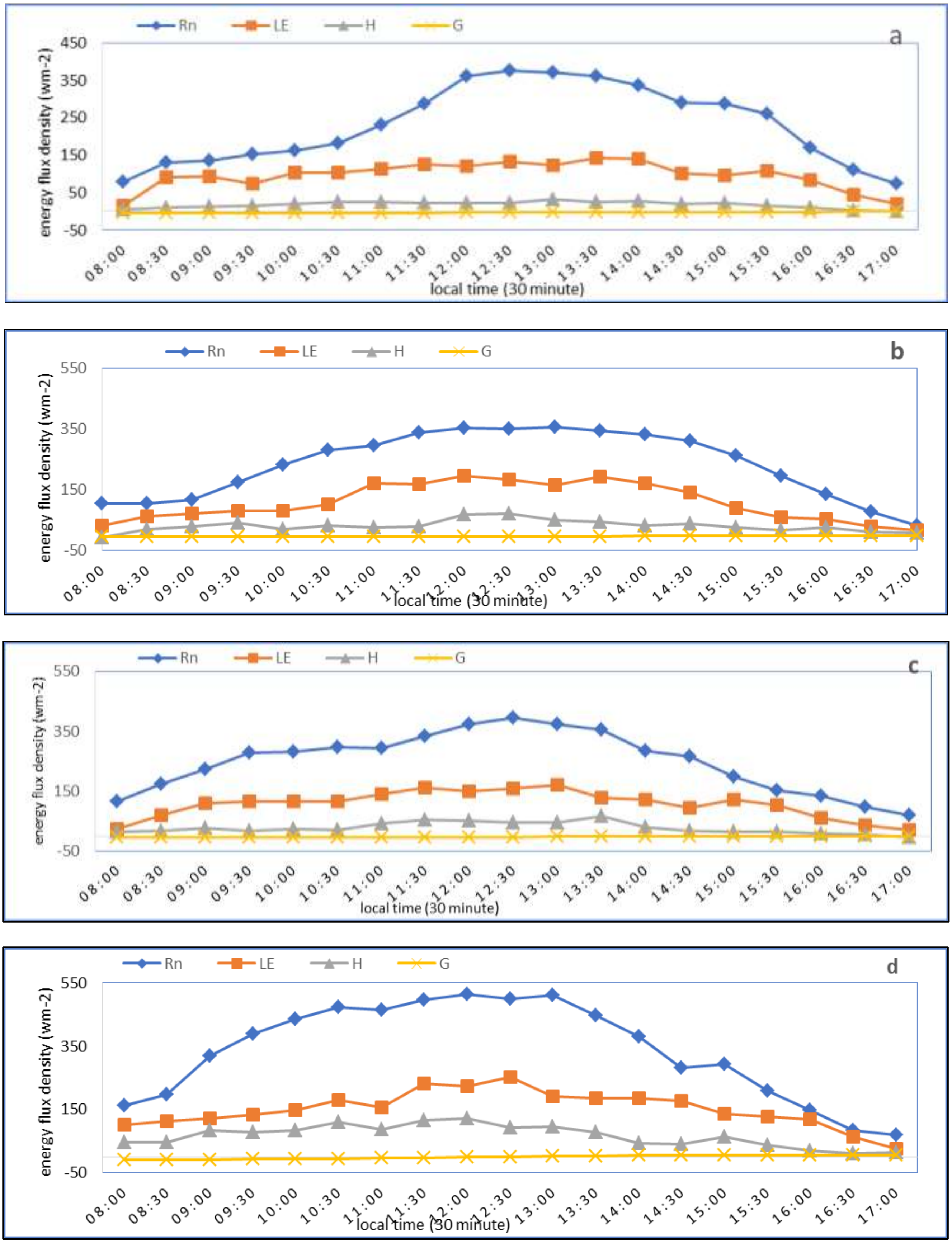

Fig 1: Diurnal pattern of energy balance at different growth stages (a) Tillering stage (b) panicle initiation (c) flowering (d) maturity of rice in 1st growing season (2018)

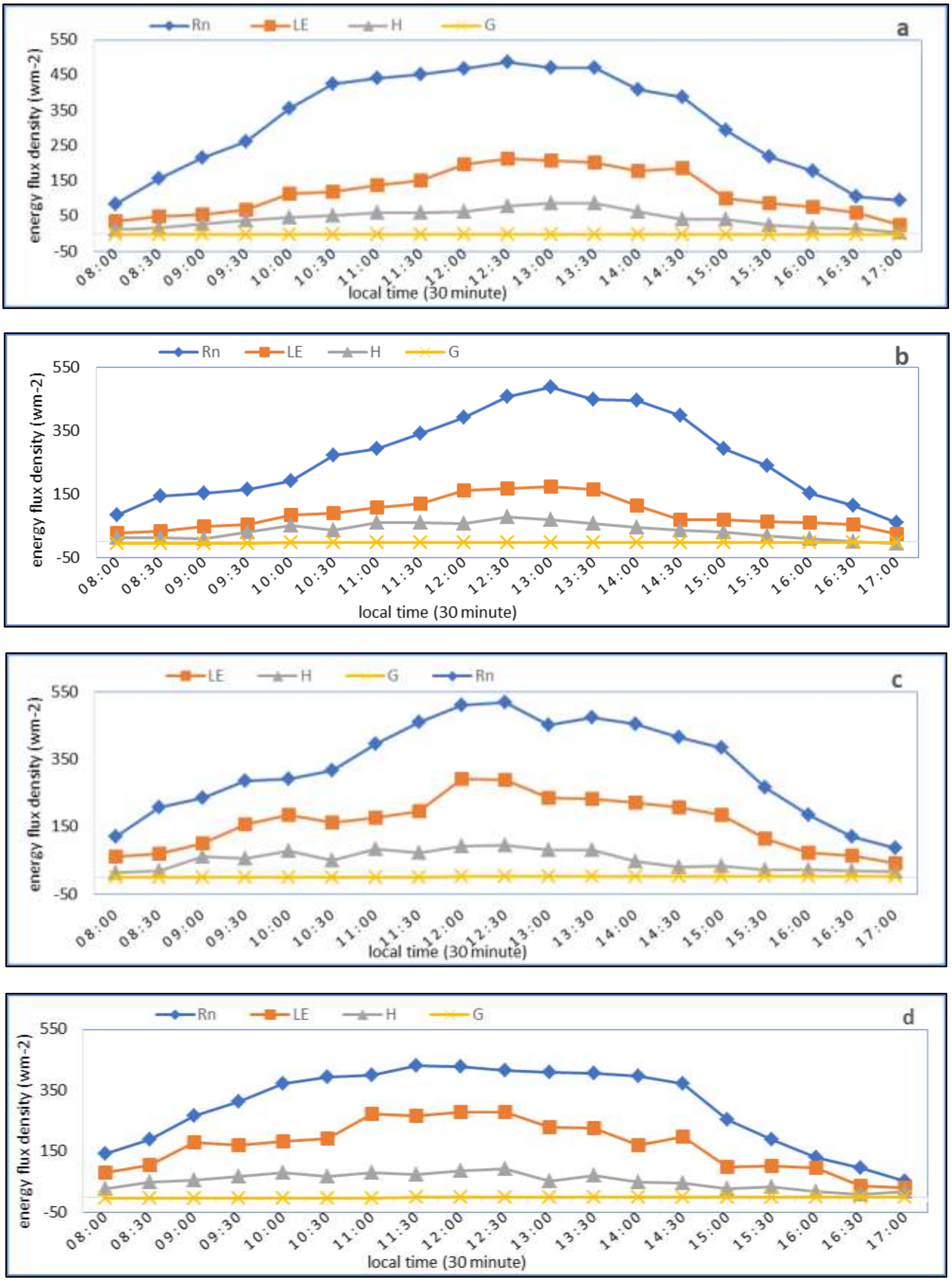

Fig 2: Diurnal pattern of energy balance at different growth stages (a) Tillering stage (b) panicle initiation (c) flowering (d) maturity of rice in 2nd growing season (2019)

Seasonal variation of energy balance components

The net radiation partitioned into sensible heat (H), latent heat (LE) and ground heal flux (G) at different stages in a daytime (8:00 to 17:00 hrs) of rice crop are given in Table: represented on seasonal variation of surface energy fluxes over rice crop. The results showed that the Rn was major component of energy balance ranges which varied from 161.16 to 340.09 Wm^{-2} where highest 340.09 Wm^{-2} was found in maturity stage and lowest 161.16 Wm^{-2} was found in tillering stage. LE was varied between 37.59 to 126.09 Wm^{-2}, where highest 126.09

Wm^{-2} was found in panicle initiation stage and lowest 37.59 Wm^{-2} was found in tillering stage. H was varied from 4.79 to 53.45 Wm^{-2}, where highest 53.45 Wm^{-2} was found maturity stage and lowest 4.79 Wm^{-2} was found in tillering stage. G was varied from-3.25 to -0.41 Wm^{-2}, where highest -0.41 Wm^{-2} was found milking stage and lowest -3.25 Wm^{-2} transplanting stage during 2018 crop growth period. Were, in 2019 crop growing season the Rn was varied between 278.76 to 376.24 Wm^{-2}, where highest 376.24Wm^{-2} was found in milking stage and lowest 278.76 Wm^{-2} was found in panicle initiation stage. LE was varied between 92.37 to 193.36 Wm^{-2}, where highest 193.36 Wm^{-2} was found in tillering stage and lowest 92.37 Wm^{-2} was found in panicle initiation stage. H was varied from 9.46 to 53.14 Wm^{-2}, where highest 53.14 Wm^{-2} was found flowering stage and lowest 9.46 Wm^{-2} was found in panicle initiation stage. G was varied from -2.60 - 0.02 Wm^{-2}, where highest -0.02 Wm^{-2} was found tillering stage and lowest -3.25 Wm^{-2} panicle initiation stage. The negative values of G because soil of experimental field was moist in all the seasons after that some energy of soil was consumed by moisture. The average radiation components were found highest at 2nd season at all stages may be due to the higher radiation interception from the atmosphere.

Table 1: Partitioning of energy balance components at different growth stages in Rice crop under two growing seasons (2018 and 2019)

Growth stages	1st season (2018)							2nd Season (2019)						
	Rn	LE	H	G	LE/Rn	H/Rn	G/Rn	Rn	LE	H	G	LE/Rn	H/Rn	G/Rn
Transplanting	224.65	98.07	13.21	-3.25	0.79	0.11	-0.03	316.19	156.56	35.99	-1.21	0.50	0.11	0.00
Tillers	161.16	77.59	4.79	-2.68	0.61	0.08	-0.04	372.30	193.36	35.89	-0.02	0.52	0.10	0.00
Panicle initiations	245.66	126.09	21.24	-2.39	0.87	0.15	-0.02	278.76	92.37	9.46	-2.60	0.33	0.03	-0.01
Flowering	270.96	118.41	23.89	-3.08	0.69	0.14	-0.02	334.31	118.28	53.14	-1.60	0.35	0.16	0.00
Milking	272.55	120.08	38.09	-0.41	0.70	0.22	0.00	376.24	168.85	44.92	-0.39	0.45	0.12	0.00
Dough	318.12	119.54	30.10	-1.82	0.55	0.14	-0.01	371.13	155.00	40.36	-1.32	0.42	0.11	0.00
Maturity	340.09	112.56	53.45	-2.02	0.47	0.22	-0.01	363.10	177.04	52.91	-1.91	0.49	0.15	-0.01
Average	261.88	104.62	26.39	-2.23	0.67	0.15	-0.02	344.58	151.64	38.95	-0.84	0.44	0.11	0.00

Partitioning of energy balance components

The total energy balance of the day time, LE was dominated at all stages in both the seasons. LE/Rn ratio on rice crop was recorded highest (0.87) in panicle initiation stage during 1st season but tillering stage was found highest (0.52) ratio in 2nd growing season. where average LE/Rn ration showed maximum during 1st season which means that more energy is dissipated into the atmosphere in the form of latent heat from the surface (Neog *et al*., 2005) [8]. H/Rn ratio was recorded highest (0.22) in milking stage during 1st season but highest (0.16) ratio was found in flowering stage on 2nd growing season. G/Rn ratio was recorded negative and some stage zero of different growth stages of rice crop due to low land area and this seasons all time moisture available on crop land. The Rn partitioned ratio was highest at LE followed by H and G was minute partitioned during both the cropping season. The variation on LE at different growth stages, its either because of crop surface area, deflection in ambient temperature or orientation of the crop. Soil moisture conditions almost all energy of Rn is consumed as LE, while small quantities of energy distributed to G and H over the day time (Khatun *et al*., 2014) [7].

Conclusion

In the present study was concluded that the both the year have sufficient soil moisture conditions. Where, LE was dominated in the energy balance components and it accounted more about 82% of Rn at all the growth stages of both growing seasons. Highest LE accumulation was observed in 2019.

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