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Bowen Ratio Measurements of Energy Budget Components over Various Ecosystems in Mymensingh, Bangladesh

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Abstract: Surface energy budget components were measured over four different surfaces in the campus of Bangladesh Agricultural University, Mymensingh, Bangladesh (24.75ºN, 90.5ºE) at the beginning of dry season (August to December 2004) using Bowen Ratio Energy Balance (BREB) technique. Under sufficient soil moisture conditions, surface energy budget during the study period was characterized by dominant latent heat flux (79% to 92% of net radiation) and negligibly small sensible heat flux with small modification by vegetation.

Introduction

Evaluation of energy balance components is very important micrometeorological aspects for scientists who wish to manage crops, grass, and forest including other vegetation successfully. Thus, different works on the measurements of these components had already been done in different parts of the world (Burba *et al.,* 1999; Harazono *et al.*, 1999; Bremer *et al.,* 2001; Brammer and Ham, 1999). Past research reports indicate that energy balance components including other micrometeorological aspects were observed over maize-soybean intercropping (Huq, 2003), rice (Khatun, 2004) and grassland (Farukh, 2004) in Bangladesh, but it was not reported over harvested paddy field so far. To conducting the research, at first attention should be given for describing the micrometeorological factors over harvested rice field for generating basic microclimatic data and to synthesize them.

In case of vegetation, foliage distribution is an important factor to modify micrometeorology especially when the size and the structure of the canopy allow a significant portion of the incident solar radiation reaching the soil surface (Cohen *et al.*, 1995). The primary components of the surface energy balance are net radiation (R_n), heat storage term (S), sensible heat flux (H), and latent heat flux (lE) or evapotranspiration (Burba *et al.,* 1999). Deep canopy acts as a strong barrier to allow radiation to penetrate the soil below the canopy. So, canopy contributes most of vapour flux of energy balance components. When crops are harvested the surface becomes open and radiation strikes the soil surface directly allowing it to contribute major H. Dry soil surface reflects more radiation than the wet surface.

Investigation on energy and water vapor exchange between soil/vegetation and the atmosphere is essential for understanding micrometeorology of plant canopy and improving meteorological environment of crops. It is also the basis for designing flux measurement of carbon dioxide and other greenhouse gases in terrestrial ecosystems.

We designed experiments to provide preliminary information on partitioning of net radiation (Rn) into latent heat flux (lE), sensible heat flux (H) and ground heat flux (G) over various ecosystems in Bangladesh.

Materials and Method

Site description

An experiment was conducted to compute energy balance components over rice field, harvested rice field, grass land and bare land at the Environmental Science Field Laboratory, Bangladesh Agricultural University, Mymensingh during August to December 2004.

Climatic status

Soil of experimental field is non-calcareous dark grey floodplain soil (UNDP and FAO, 1988) with sandy loam texture. The p^H value of the soil ranges from 5.9 to 6.5 (According to Soil Science Department, BAU, Mymensingh). The experimental site is under subtropical climate characterized by moderately high temperature and heavy rainfall during the kharif (monsoon) season (April to September) and scanty rainfall with moderately low temperature during Rabi (dry) season (October to March). The climatic conditions of the observation days are shown in Table 1.

Table 1. Records of the monthly weather parameters during the study period (August-December 2004)

Month	Air temperature (^oC)	Air pressure (mb)	Wind speed (Km/hr)	Rainfall (mm)	Sunshine hour
August	29.2	999.6	2.2	253	164
September	27.7	1004.5	2.3	270	65
October	26.4	1010.4	1.3	488	201
November	22.9	1012.6	0.6	00.0	225
December	20.1	1013.0	0.6	18	197

Cultural practices

In rice field, 33-day old seedlings were transplanted in experimental plots on the 10th August 2004 following standard cultural practices to grow rice. Harvested rice field appeared after harvesting mature rice. Grasses grow naturally in grassland. Grassland was cleaned by plowing to make bare land.

Plant height, canopy width and LAI of rice plant during the data collection period were 92 to 95cm, 54 to 58 cm and 2.8 to 3.0 respectively, while the height of rice straw was 10-15 cm and that of grass was 5-10 cm. Soil moisture content except for the irrigated rice field ranged from 39 to 48.

Flux measurement

The energy budget components were calculated using the following equation (*e.g*. Ham *et al*., 1991).

$$Rn = H + lE + G \text{ -------- } (1)$$

Rn and ***G*** were measured directly using a naturally ventilated net radiometer (Q*6, REBS) and soil heat flux plates (MF-81, EKO), respectively. ***H*** and ***lE*** were determined using BREB Method (*e.g*. Rosenberg *et al*., 1983; Harazono *et al*., 1999). The Bowen ratio (β) was calculated from vertical gradients of air temperature and water vapor pressure, which were measured with temperature-humidity sensors (HMP-45A, Vaisala) equipped with homemade ventilators.

$$\text{Bowen Ratio, } \beta = \frac{CpP\,(Ta_1 - Ta_2)}{0.622l\,(ea_1 - ea_2)} \text{ ----------------------- } (2)$$

Where, C_p is the specific heat of air at constant pressure (1004 J Kg^{-1}), P is air pressure in mb, 0.622 is the psychrometric constant, air temperature $T_{a1,2}$ and the vapour pressure $e_{a1.2}$ in ^0C and haP at two heights, respectively .

e_a was calculated from the following formula -

$$e_a = \frac{RH \times e_{s(T_a)}}{100} \text{ ------------------------ } (3)$$

Where, $e_{s\ (Ta)}$ is the saturation vapour pressure in haP of pure water at T_a and was calculated by Goffgratch formulation

$$\log e_{s(T_a)} = -7.90298\left(\frac{T_b}{T} - 1\right) + 5.02808\ \log\frac{T_b}{T} - 1.3816 \times 10^{-7}\left(10^{11.344(1-\frac{T}{T_b})} - 1\right)$$
$$+ 8.1328 \times 10^{-3}\left(10^{-3.49149\,(\frac{T_b}{T}-1)} - 1\right) + \log(1013.25) \text{ ---} (4)$$

Where, T_b is the steam point temperature (373.16 K) and T is the air temperature.

The l in Jkg^{-1} was calculated from the following formula

$$l = 250080 - 2367\overline{T}_a \text{ --------------------------- } (5)$$

$$\text{Sensible heat flux, } H = \frac{R_n - G}{1 + \beta^{-1}} \text{ --------------------------- } (6) \text{ and}$$

$$\text{Latent heat flux, } lE = \frac{R_n - G}{1 + \beta} \text{ ------------------------------ } (7)$$

Results and Discussion

Diurnal variation of energy budget components

Diurnal trends of ***Rn***, ***lE***, and ***G*** followed the diurnal course of global radiation (***Rs***) (Figure 1). The ***lE*** showed maximum values of 420 W m^{-2} over rice field, 280 W m^{-2} over harvested rice field, 390 W m^{-2} over grassland, and 270 W m^{-2} over bare land. ***H*** showed almost zero before and after midday having very small positive values (5~15 W m^{-2}) around midday over all the ecosystems under study.

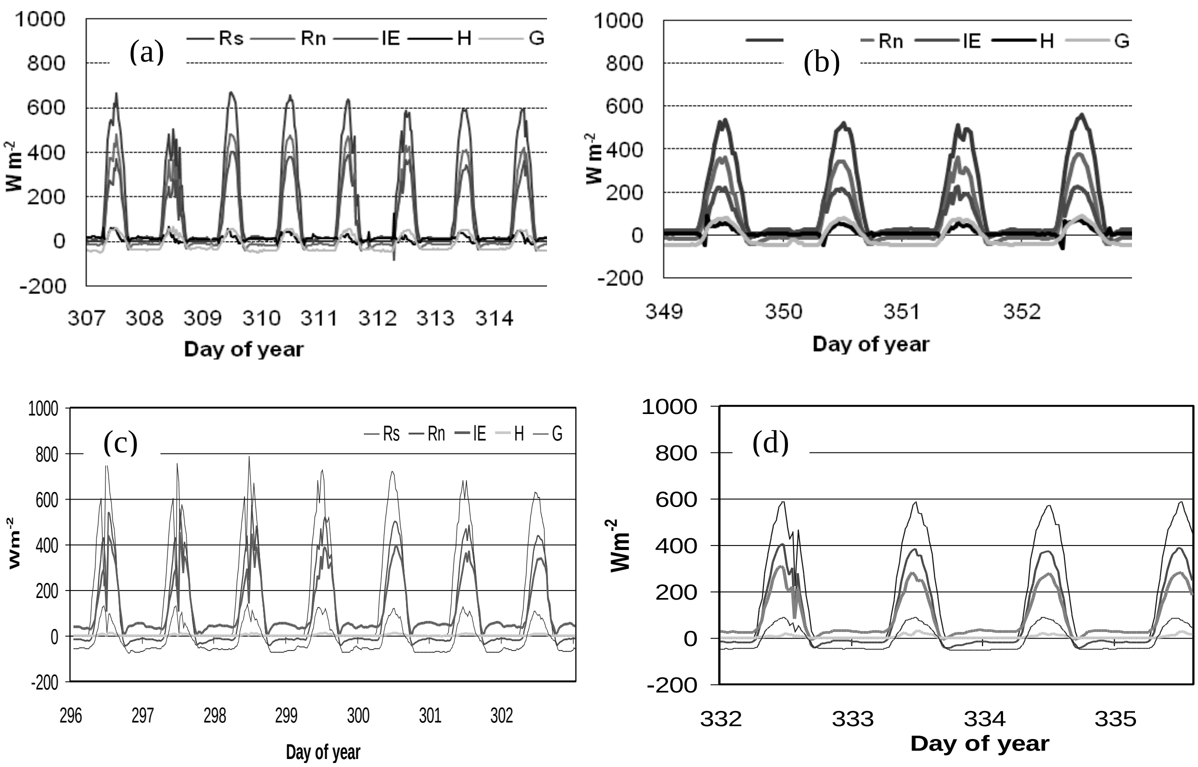

Fig 1. Diurnal courses of energy budget components over: (a) irrigated rice field; (b) harvested rice field; (c) grassland and (d) bare land

Daytime energy budget

Day-to-day variations of energy budget components over the irrigated rice field and the grassland in the daytime (6:00 to 18:00h) are shown in Figure 2, and averaged daytime energy budget of the four ecosystems are shown in Figure 3.

In the total energy budget of the daytime, ***lE*** was dominant at all of the four ecosystems, while *H* was minor. ***lE/Rn*** was 0.92 on average at the irrigated rice field, 0.82 at the harvested rice field, 0.84 at the grassland and 0.79 at the bare land. ***H/Rn*** was the largest at the bare land (0.04 on average). ***G/Rn*** was greater than ***H/Rn*** and ranged from 0.07 at the irrigated rice field to 0.15 at the bare land and the harvested rice field.

These characteristics in surface energy budget have often been observed over crop fields under sufficient soil moisture conditions. For example: 1) when the soil is moist, almost all of energy supplied by ***Rn*** is consumed as ***lE***, while small quantities of energy are distributed to ***G*** and ***H*** from early morning until about 1500 hours (Fritschen and van Bavel, 1962); 2) in well irrigated cotton fields, ***lE*** ranged from 77 to

104% of ***Rn*** (Ham *et al*. 1991) and 3) in a cotton field, ***lE*** was 90 to 110% of ***Rn*** when soil surface was wet and water was not limiting (Ritchie, 1971).
Observed ***G/Rn*** and ***H/Rn*** were similar to the values reported by a previous study in soybean filed at 35.46°N by one of the co-authors: in E-W soybean rows, 14 to 18% of ***Rn*** was partitioned into ***G*** and 2 to 7% of ***Rn*** into ***H***, while in N-S soybean rows, 6 to 9% of ***Rn*** was partitioned into ***G*** and 1 to 10% of ***Rn*** was into ***H*** (Baten *et al*., 1997).

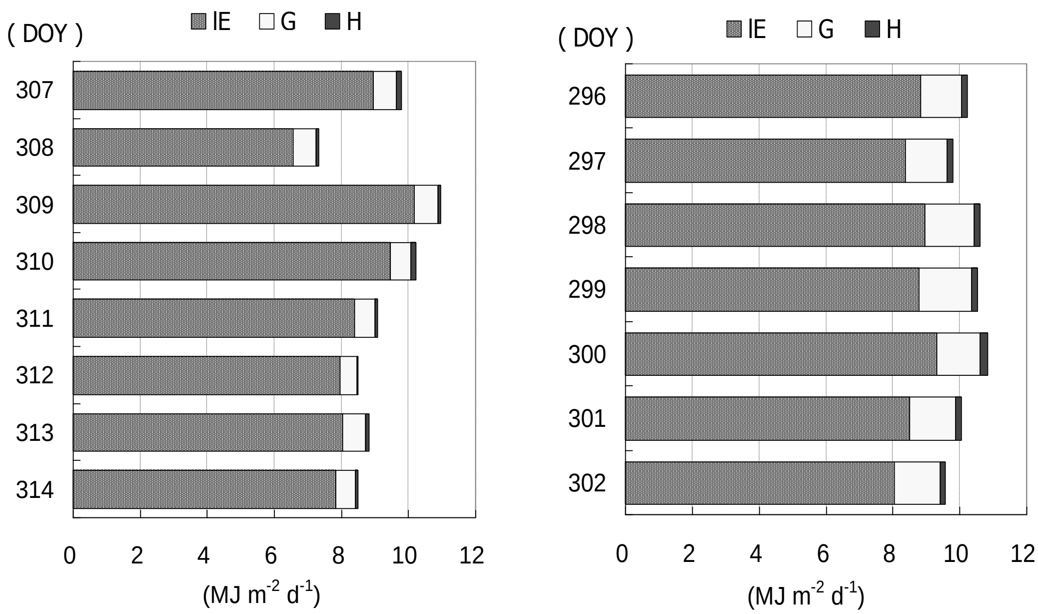

Fig 2. Day-to-day variations of daytime energy budget components: (a) irrigated rice field and (b) grassland

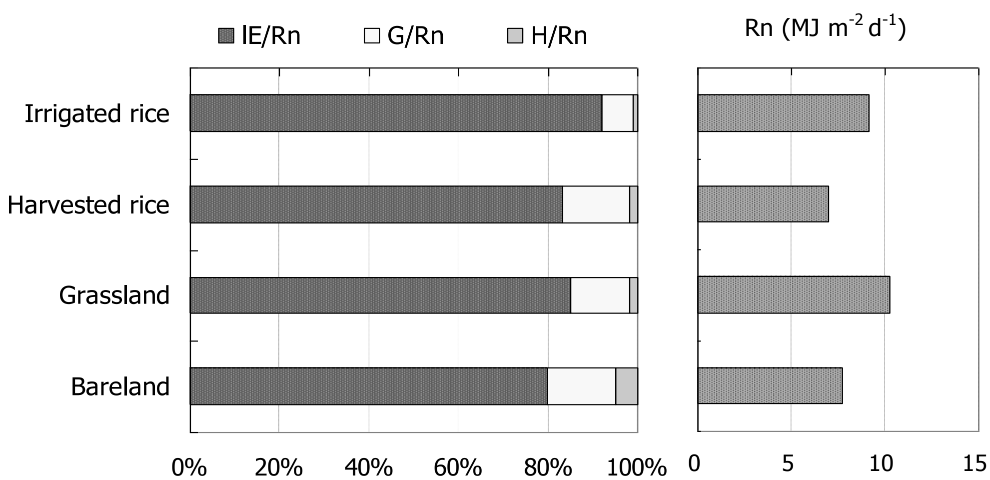

Fig 3. Comparison of averaged daytime energy budget components over four ecosystems.

Conclusions

In the present study conducted at the beginning of dry season under sufficient soil moisture conditions, ***lE*** was dominant in the surface energy budget, and it accounted for about 80% or more of ***Rn*** at all of the four ecosystem types. Further studies in other periods of the year, including rainy season, are desirable for understanding seasonality of surface energy budget in typical ecosystem types in Bangladesh.

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